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This programed course, intended primarily for registered nurses and particularly for those returning to practice after a period of retirement, may also have value for other nursing personnel. The general objective is to assist the nurse in the hospital to improve the quality of the nursing care given to the patient placed on a closed chest drainage system. Units are Anatomy and Physiology, Rationale of Therapy, and The Apparatus. The material is to be used by the individual student, and two separate sessions totaling three to four hours are recommended for the completion of the course. An optional review is included following the section on anatomy and physiology for the use of students who, on the basis of their knowledge, desire to omit this section. Numerous diagrams are presented and a reference list is included. (JK)

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CLOSED DRAINAGE OF THE CHEST

a programed course for nurses

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service

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Washington, D.C. 20201

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FOREWORD

The need for the professional nurse in the hospital to update her knowledge is well recognized. Equally recognized are the factors of insufficient time, shortage of staff, and problems of scheduling which make it difficult to provide opportunities for inservice education programs. Other means must be found which the nurse herself can use to keep abreast of rapid developments in nursing care.

As part of its overall responsibility to improve nursing services nationwide, the Division of Nursing is assisting in the communication of new nursing knowledge and techniques and in the use of new media. Because some of the characteristics of programed instruction, such as standardization of the content, self-containment of the instruction, and active involvement of the student, have made it appear to be especially suitable for the inservice education of the professional nurse, the Division of Nursing prepared this self-instructional course. The subject chosen is one about which many nurses feel a need to improve their knowledge, particularly those who are returning to practice after several years of retirement.

This course is intended as a review by the registered nurse in the hospital and as an adjunct to basic instruction. It can also have value for other nursing service personnel. The course has been found to be both practicable and effective by professional nurses with varying educational preparation and in a variety of positions. We hope this publication will provide a means whereby many more can become knowledgeable about this important procedure.

JESSIE M. SCOTT
Chief
Division of Nursing

ACKNOWLEDGMENTS

Prepared under the direction of
ELINOR D. STANFORD, R.N., M.S., *Director*
Nursing Research Field Center
Division of Nursing

CONSULTANTS

BETTY J. DIETRICH, R.N., M.S., *Lecturer in Nursing,*
University of California School of Nursing, San Francisco, California

KENNETH H. HYATT, M.D., *Deputy Chief,* Research Service
CHARLES H. LITHGOW, M.D., *Chief,* Surgical Service
WILLIAM M. SMITH, M.D., *Chief,* Medical Service
JOHN M. VOGEL, M.D., *Chief,* Research Service
U. S. Public Health Service Hospital
San Francisco, California

BARBARA WACHNER, B.A., *Programed Instruction Consultant,*
Santa Barbara, California

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Illustrated by Mickey Wilson

CONTENTS

INTRODUCTION

It is only in the recent past that intrathoracic surgery has become widespread; therefore, some of the procedures and equipment associated with it may still be unfamiliar to many people who must work with them. Such is the case with closed chest drainage apparatus. When a professional nurse who has never had the opportunity to study this apparatus must care for a patient who has been placed on it, she is ill-equipped to provide safe nursing care. This is true too of the nurse who once learned about this type of equipment but has never, or infrequently, used the knowledge.

In nearly every hospital, the professional nurse can consult a procedure manual to check on unfamiliar devices. From the manual, she may learn something about the appearance of the apparatus, some details of its mechanics, and a few general precautions. In some cases, especially when the device is simple or when the condition for which it is used is not a critical one, the information contained in the manual may be sufficient.

The workings of a closed chest drainage system are not difficult to understand and can be explained as simple procedures. However, the patient who has undergone intrathoracic surgery and who has been placed on this apparatus *is* in critical condition during the immediate postoperative period. Only a slight mishap involving the drainage system can result in his death within minutes. Or the mishap may result in prolonged hospitalization or a second thoracotomy to correct complications. When something goes wrong, complications generally occur rapidly, and a physician may not arrive in time to prevent them.

It seems evident, therefore, that the nurse who is caring for a patient on closed chest drainage should have enough knowledge so that she is capable of judging the individual situation accurately — and capable of taking corrective action if and when it is essential to do so. Not only should she understand the mechanical functioning of the apparatus, but also she should be able to relate this functioning to the basic concepts of anatomy and physiology which are pertinent. In other words, she should understand what is taking place within the patient's chest as well as within the equipment — and be able to correlate the two.

In the first part of this course, we'll review certain basic information about the anatomy of the chest, gas pressures, and the mechanics of respiration. We will not go into these subjects in great detail but will limit ourselves to a discussion of only those

facts which are necessary to an understanding of closed chest drainage. Secondly, we intend to talk about the reasons for this type of therapy and the goals to be achieved by it.

In the third section, we'll describe the *water-seal* drainage system — how it looks and how it works. We'll talk about things that can cause malfunction, about ways to recognize malfunction, and about what the nurse can do in such a situation. Then we'll go on to a discussion of the *mechanical suction* apparatus, pointing out how this setup differs from the simple water-seal and covering the special points which pertain only to the mechanical device. Interwoven throughout the discussion of apparatus will be a description of specific care of the patient.

General Objective:

To help the registered nurse in the hospital improve the quality of the nursing care she directs as well as that which she gives to the patient who has been placed on a closed chest drainage system.

Specific Objectives:

***Expectations*:**

On completion of this course, the nurse will be able to:

1. Describe features of normal anatomy and physiology which are pertinent to closed drainage of the chest.
2. Explain the purposes of therapy with a closed chest drainage apparatus.
3. Describe the appearance and functioning of water-seal and mechanical suction apparatus.
4. List the essential elements of related nursing care.

***Hopes*:**

On completion of this course, it is hoped the nurse will be able to:

1. Set up a water-seal and/or mechanical suction system which functions properly.
2. Perceive the patient in relation to the apparatus.
3. Take appropriate action on the basis of the above perception.

NOTE TO READER

This book exemplifies a tutorial method of self-instruction and therefore it is different from the usual book. For example, you do not read the pages consecutively. Instead, you must follow the directions you will find at the end of the page you're reading.

Throughout this course, you will be asked to answer multiple-choice questions. When you have selected the answer you think is correct, you will turn to the page number shown beside that answer.

When you answer a question correctly, you will move ahead to the next bit of information and a new question. But when you answer incorrectly, you will receive further explanation and be sent back to try again. Your rate of progress, therefore, will depend on your choice of answers.

Although it has been found that the professional nurse can complete the course in one session of from three to four hours, it is recommended that it be studied in two separate sessions.

Optional Procedures

If you think you already have enough knowledge of the basic anatomy and physiology as well as some of the principles of physics which are pertinent to closed drainage of the chest, you may wish to begin the course with Section II. In this case, turn to page 78.

If you're uncertain about whether you should begin the course with Section I or with Section II, you may wish to try the review questions which are based on Section I. In this case, turn to page 59.

If you wish to start the course at the beginning, turn to page 1.

Section I

ANATOMY AND PHYSIOLOGY

Let's begin by meeting our patient, Mr. Marlin, who is resting quietly in a two-bed room. Mr. Marlin is a 52-year-old salesman who entered the hospital today in preparation for intrathoracic surgery.

In order to understand what will be going on within Mr. Marlin's chest during and after surgery, we'll briefly review some facts about the anatomy of this structure: Just beneath the layer of skin and fat which covers Mr. Marlin's chest lies the barrel-like chest wall — which encloses the front, sides, and back of the thoracic (chest) cavity.

The chest wall is composed of the thoracic skeleton (ribs, sternum, and thoracic vertebrae) which is interlaced and covered with the intercostal muscles to form a solid, semi-rigid structure. The lower boundary or floor of the thoracic cavity is the diaphragm, which is composed of muscle.

Please go on to page 6.

You're on the wrong page, so apparently you haven't understood the instructions.

In this book, you do not read the pages consecutively. To progress through the course, you *must* follow the directions you will find at the end of the page you're reading.

Please go back to page 1 and then turn to the page number indicated at the end of that page.

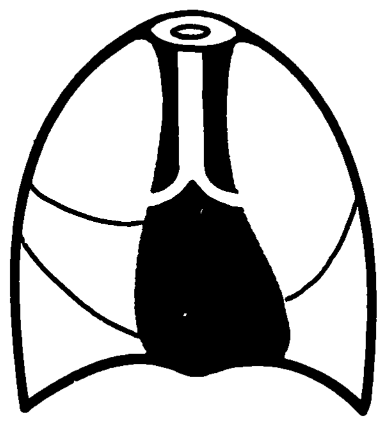
YOUR ANSWER: The mediastinal area partitions the chest cavity so that each lung occupies its own closed cavity.

Correct. The interior of the chest cavity can be divided into three major areas: two separate lung chambers plus the mediastinal area.

Now let's consider this: Normally, air enters and leaves Mr. Marlin's thoracic cavity only through the trachea; the trachea conveys the air into and out of the lungs via the bronchi. Inside the lungs, the exchange of gases (oxygen and carbon dioxide) between air and blood takes place within the millions of tiny air sacs (the alveoli) in the lung tissue.

You'll recall we mentioned earlier that the bronchus, together with certain vessels, is sometimes called the "root" of the lung. Each lung lies free in its own chamber except at the point where its "root" is attached to the mediastinum.

Look at this diagram; then decide which of the structures listed below are airtight. (Note: From here on in the course, the dark area in the center will represent the mediastinal area.)



The lungs. page 7
The lung chambers. page 10
The bronchi. page 12

(from page 10)

YOUR ANSWER: Normally, each lung contains enough air to fill the alveoli.

Not quite true.

Although the alveoli do contain some air at all times, they are not always *filled* with air. Following expiration, for example, they contain less air than following inspiration.

The important point here is this: not only can the elastic fibers of the lung be stretched, but also they *are* normally stretched. And they are maintained in this stretched, or extended, position so that the lung occupies its entire cavity.

Now RETURN to page 10, look at the diagram again, and select the correct alternative.

YOUR ANSWER: The mediastinal area partitions the chest cavity so that each lung is bound to the other by connective tissue.

Wrong.

The mediastinal connective tissue ensheaths and binds together structures which are located approximately in the center of the thoracic cavity. This includes the esophagus, trachea, heart, aorta, other major vessels, thymus, nerves, etc. The lungs are located on each side of the thoracic cavity.

The mediastinal area, which is like a partition in the center of the chest cavity, divides the interior of the cavity so that each lung lies in its own separate chamber.

Please RETURN to page 13, look at the diagram again, and select the correct alternative.

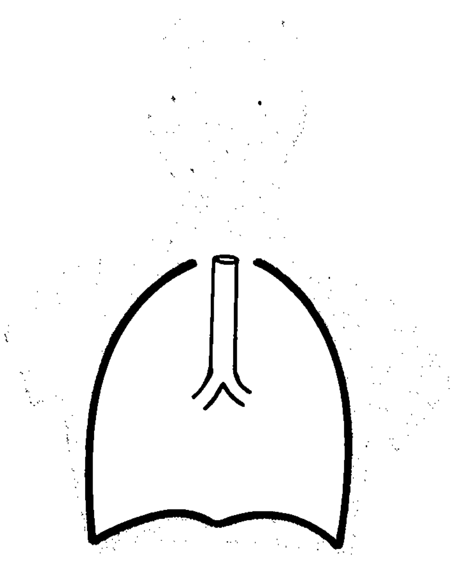
(from page 1)

Although Mr. Marlin's thoracic cavity does contain two passageways which are open to the outside environment (the esophagus and trachea), the cavity itself is a *closed* structure. It is closed at its upper boundary by the superior mediastinum, which is connective tissue.

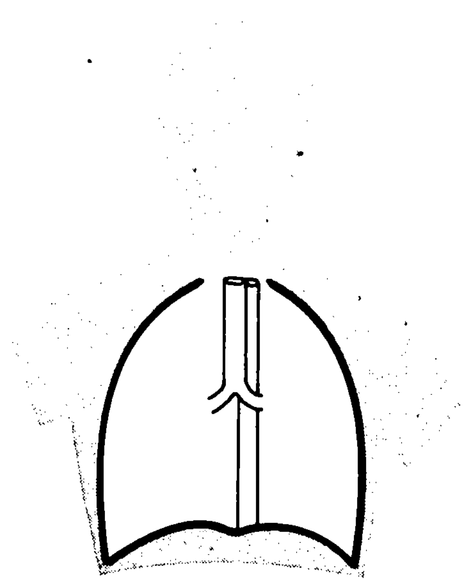
Mr. Marlin's esophagus and trachea pass downward into the encircling superior mediastinum on their way to the interior of the chest. The esophagus, of course, continues downward through the diaphragm to the stomach. About midway into the interior of the chest, the trachea ends in an inverted Y shape. Each of the two branches of the Y is a bronchus which, together with certain blood vessels, sometimes is called the "root" of the lung.

Now here is your first question. (Select the alternative you think is correct and turn to the page number shown beneath it.)

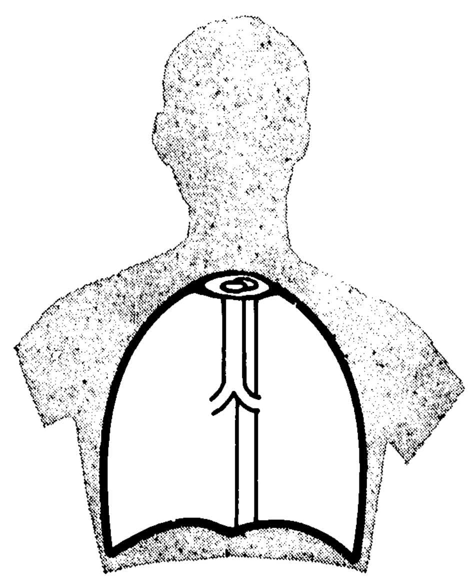
Which of the following simplified diagrams illustrates the situation we've described in the chest?



page 9



page 11



page 13

YOUR ANSWER: The lungs are airtight.

Not true.

If that statement *were* true, the lungs would not be able to perform the function assigned to them, would they?

Certainly the lungs are *not* airtight. With every inspiration, they receive air from the outside atmosphere. Inspired air travels into the lungs via the trachea and bronchi.

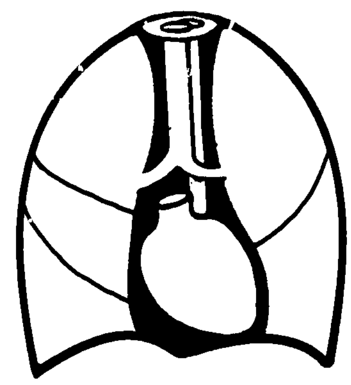
If you will go back to the previous page, read the information again, and look at the diagram, you will see that the cavities which house the lungs not only are closed, but also are airtight.

Please RETURN to page 3.

(from page 13)

YOUR ANSWER: The mediastinal area partitions the chest cavity so that each lung contains three major areas.

Perhaps you misread the sentence we asked you to complete, or maybe you misunderstood.



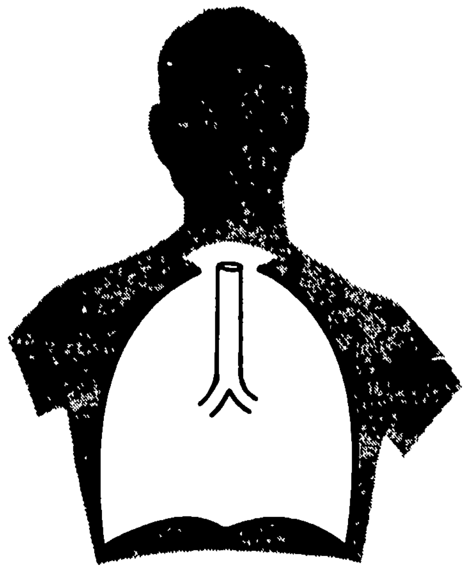
In case you did not understand the information we gave you, let's go over it again. Here's the diagram once more:

You'll notice that the left lung is divided into two lobes while the right lung contains three lobes. The right lung is slightly larger than the left. This is incidental, however, to the idea we're trying to convey.

The important concept is this: The interior of the thoracic cavity can be divided into three major areas — a separate chamber for each lung (two areas) plus the mediastinal area, which acts as a partition between the two lung chambers.

Study the diagram again; then RETURN to page 13 and select the correct alternative.

YOUR ANSWER: This diagram illustrates the situation we've described in the chest:



Almost.

And, in fact, you chose the diagram which shows structures which are relevant to this course. The diagram you selected represents the *closed* chest cavity with the trachea entering it through the superior mediastinum.

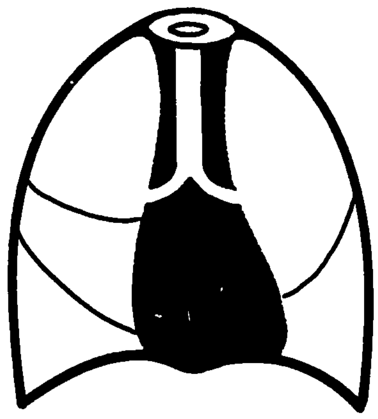
Apparently you forgot that we described the pathway of the esophagus which also passes into and through the chest — and through the diaphragm.

Please RETURN to page 6 and choose the diagram which is more complete than this one.

YOUR ANSWER: The lung chambers are airtight.

Right. The cavities or chambers which contain the lungs are closed cavities, and they are airtight.

We said that each lung lies free in its chamber, being attached to another structure (the mediastinum) only at its "root." And we mentioned the tiny air sacs, or alveoli, of which lung tissue is composed. Normally, these alveoli contain at least a small amount of air at all times.



If Mr. Marlin's lungs contained no air, they would occupy only about one-third of their chambers. Instead, however, they normally occupy their entire chambers, as shown in the diagram.

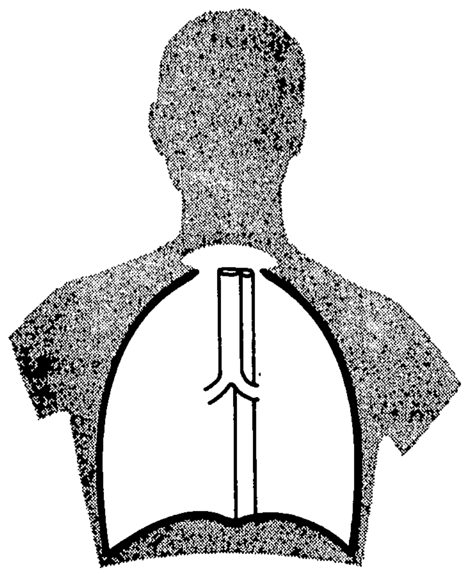
Mr. Marlin's lungs are able to increase so much in size because they are composed of elastic fibers which can be stretched. Indeed, these fibers are continually stretched — and maintained in that position.

Choose the alternative which correctly completes this statement. Normally, each lung:

Contains enough air to fill the alveoli.	page 4
Occupies only one-third of its airtight chamber.	page 14
Is extended so that it fills the available space.	page 17

(from page 6)

YOUR ANSWER: This diagram illustrates the situation we've described in the chest:



No, you forgot one very important detail.

Remember we said that the thoracic cavity is a *closed* structure. Its outer limits are the chest wall, the diaphragm, and the superior mediastinum.

The esophagus and trachea enter the chest cavity through the superior mediastinum which ensheaths these two open passageways.

RETURN to page 6 and choose the diagram which represents the situation we've described.

YOUR ANSWER: The bronchi are airtight.

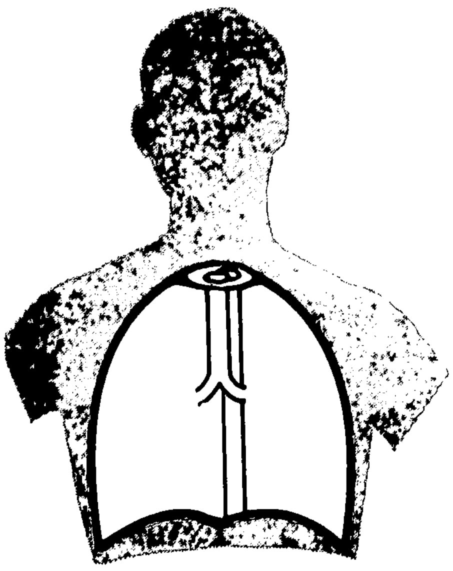
No.

The bronchi are the passageways through which air enters and leaves the lungs; they could not of course be airtight.

As we said previously, the mediastinal area partitions the interior of the thoracic cavity so that there is an independent closed cavity on each side of the central partition. The spaces on each side of the mediastinal partition *are* airtight cavities.

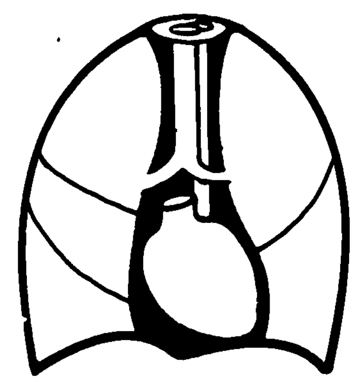
Please RETURN to page 3 and choose the correct answer.

YOUR ANSWER: This diagram illustrates the situation we've described in the chest:



You're right. It represents the *closed* thoracic cavity, with its outer limits being the chest wall, diaphragm, and superior mediastinum. Also shown are the pathway of the trachea and of the esophagus.

Now look at *this* diagram of Mr. Marlin's chest: We've added the heart, left lung (with two lobes), and right lung (three lobes). Note that the interior of the thoracic cavity can be divided into three distinct areas: (1) the mediastinal area (approximately in the center of the cavity) and (2) and (3) a separate chamber for each lung.



The mediastinal area (of which the superior mediastinum is the upper boundary) consists of connective tissue which ensheaths and holds together the esophagus, trachea, heart, aorta, other major vessels, etc. This area acts as a flexible partition which extends from front to back and top to bottom of the thoracic cavity.

(Now choose the alternative which correctly completes the following sentence.) The mediastinal area partitions the chest so that each lung:

Occupies its own closed cavity. page 3
Is bound to the other by connective tissue. page 5
Contains three major areas. page 8

YOUR ANSWER: Normally, each lung occupies only one-third of its airtight chamber.

Wrong.

Normally, the lung occupies its entire airtight chamber.

Perhaps we confused you by telling you how Mr. Marlin's lungs would look if they contained *no* air. If that were possible, they would be only about one-third as large as they generally are in a living person.

Normally, of course, Mr. Marlin's lungs *would* contain air. And the elastic lung tissue would be extended and *maintained* in an extended position.

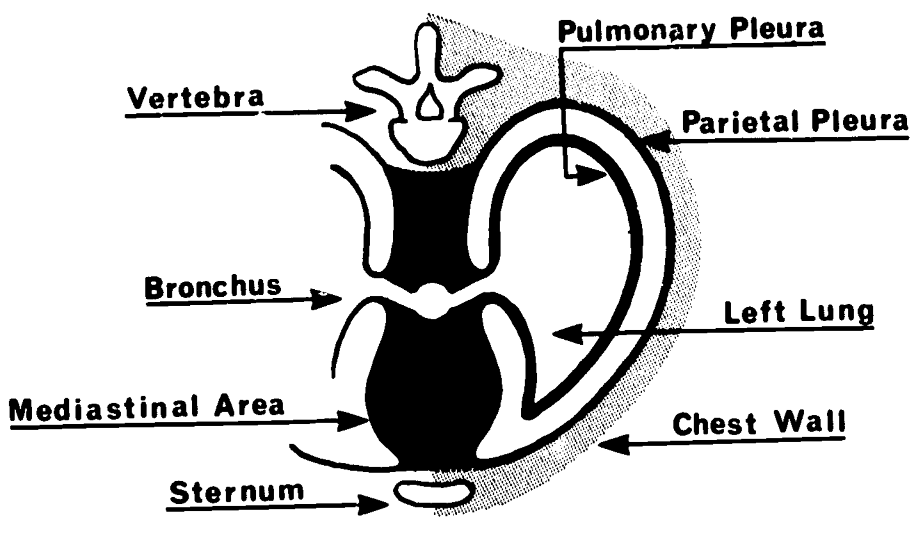
RETURN to page 10, look at the diagram again, and select the correct answer.

YOUR ANSWER: A pulling force maintains the lungs in an extended position.

That's right. The constant force required to hold the elastic lungs in their extended position is similar to that needed to keep a rubber band stretched.

As we noted before, we're going to discuss some of the factors which appear to be involved in holding the lungs in an extended position. As part of our explanation, here's another fact about Mr. Marlin's anatomy:

In some of our previous diagrams, you have seen that the boundaries of each airtight lung chamber are the chest wall, diaphragm, and mediastinal area. All of these boundaries are lined by a membrane called the *parietal* pleura. The surfaces of the lung are covered by a similar membrane, called the *pulmonary* (or visceral) pleura. These two pleurae are *continuous* with each other (see the diagram).



CROSS-SECTION

Study the diagram and then decide which alternative correctly completes the following statement. The parietal and pulmonary pleurae:

Enclose the mediastinum.	page 18
Line the chest wall.	page 20
Form a closed sac.	page 23

(from page 23)

YOUR ANSWER: Normally, the pleural space is an air space between the chest wall and lung.

Wrong. Normally, there is no air between the chest wall and lung.

Remember that the lung is contained in an *airtight* chamber, the outside boundaries of which are the chest wall, diaphragm, and mediastinum.

These boundaries are lined by the parietal pleura while the lung is covered by the pulmonary pleura. Together the parietal and pulmonary pleurae form a structure similar to a closed sac from which all air has been removed. The interior of this closed sac is sometimes called the pleural space.

Please RETURN to page 23 and select the correct answer.

YOUR ANSWER: Normally, each lung is extended so that it fills the available space.

You are correct.

Each lung does contain elastic fibers which can be stretched, and normally they *are* stretched. In fact, Mr. Marlin's lungs normally are extended to about three times their unexpanded size; they are maintained in this extended state so that they fill their chambers.

(Note: There are various theories about what it is that maintains the lungs in a stretched position. And later in the course, we will quote several authors who describe some of the factors which may be involved. Since we believe that some explanation of this phenomenon is essential to this course, we have arbitrarily chosen to discuss some of the factors which appear to be significant.)

Now let's think about this: All of us know that in order to stretch something that is elastic—such as a rubber band, for example—you have to pull on it. And you must continue to pull on it if you want to keep it in a stretched position. If you "let go," the rubber band recoils (usually with a snap). It returns to its pre-stretched size.

In some ways, the elastic fibers of the lungs are like rubber bands. When stretched and then released, they rebound in the same way. For the moment, however, we're going to consider only the extension of these fibers; we'll say more about their recoil tendency later in the course.

Now answer this question: What maintains the lungs in an extended position?

A pulling force.	page 15
Recoil action.	page 19
Elastic lung tissue.	page 22

(from page 15)

YOUR ANSWER: The parietal and pulmonary pleurae enclose the mediastinum.

Not exactly.

It's true that the mediastinal area is lined by one of these two membranes—the *parietal* pleura. The parietal pleura also lines the chest wall and diaphragm.

The lung is covered by a membrane called the *pulmonary* pleura.

We said that the parietal and pulmonary pleurae are *continuous* with each other. In other words, if we could remove these two pleurae intact from the body, we would find that they actually are one structure.

Please RETURN to page 15 and look at the diagram again. Then select the correct alternative.

(from page 17)

YOUR ANSWER: Recoil action maintains the lungs in an extended position.

No, that's wrong.

It's *because* of their tendency to rebound or recoil that there must be a force which holds them in an extended position.

We used the rubber band for our analogy because it has the same recoil tendency as an elastic fiber of the lung; you'll remember that lung tissue is composed of elastic fibers. Some things (chewing gum, for instance) are "stretchable" but don't have this tendency to spring back.

In order to maintain a rubber band (or elastic lung) in a stretched position, its tendency to recoil must be continuously overcome; it must be pulled on constantly.

Please RETURN now to page 17 and choose the correct answer.

(from page 15)

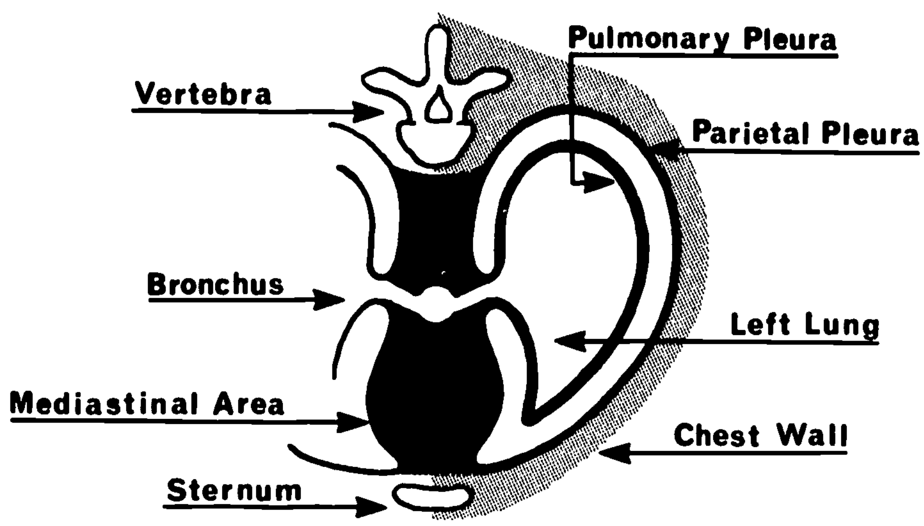
YOUR ANSWER: The parietal and pulmonary pleurae line the chest wall.

Yes, but they do more than that.

And in reality, only the parietal pleura lines the chest wall, while the pulmonary pleura covers the surfaces of the lung.

The parietal pleura also lines the mediastinal area and the upper surface of the diaphragm.

Here's the diagram again:



CROSS-SECTION

The important thing to notice in this diagram is that the parietal and pulmonary pleurae are *continuous* with each other. If we could remove these two pleurae (and keep them intact), we would find that they actually are one structure.

Look at the diagram until this is clear to you; then RETURN to page 15 and select the correct alternative.

YOUR ANSWER: Normally, the pleural space is a space between the parietal and pulmonary pleurae.

Not quite.

The point is that normally there is no space between these two membranes. So even though the lung chamber is often called the pleural space, in the normal situation, it is not a space at all.

The interior of the "closed sac" formed by the pulmonary and parietal pleurae can *become* a space, however, under certain conditions; we'll discuss these conditions later in the course.

Please RETURN to page 23 and choose the correct answer.

YOUR ANSWER: Elastic lung tissue maintains the lungs in an extended position.

Not exactly.

It's true that lung tissue must be elastic if it is to be extended and maintained in that position. But elasticity in itself does not extend the lungs.

Remember that the elastic fibers of the lungs are similar to rubber bands in that they have the same tendency to recoil. In order to maintain a rubber band (or elastic lung) in a stretched position, its tendency to recoil must be continuously overcome; it must be pulled on constantly.

Please RETURN to page 17; reread it if you think you need to, and then choose the correct answer.

YOUR ANSWER: The parietal and pulmonary pleurae form a closed sac.

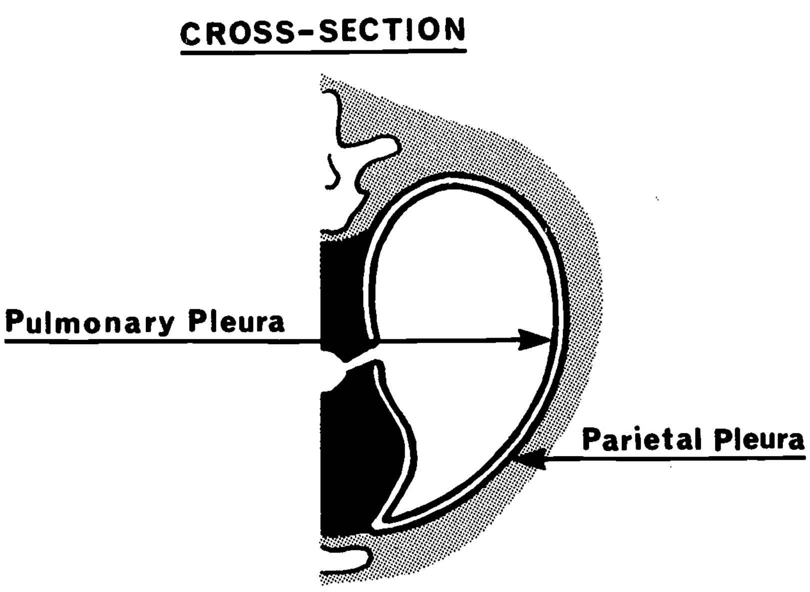
Right! That's what we hoped you would see in the diagram.

If we could remove these two pleurae *intact,* we would find that they form a closed sac.

Now to make certain we're not misleading you, look at *this* view of Mr. Marlin's normal structure:

Note that there is *no space* between the pulmonary and parietal pleurae. The "closed sac," then, is something like a completely sealed plastic bag from which all air has been removed.

Even though the outside boundaries of the "airtight lung chamber" we've been talking about are the chest wall, diaphragm, and mediastinum, this lung chamber is often called the *pleural* space or cavity (other common names are the intrapleural space and the pulmonary cavity).

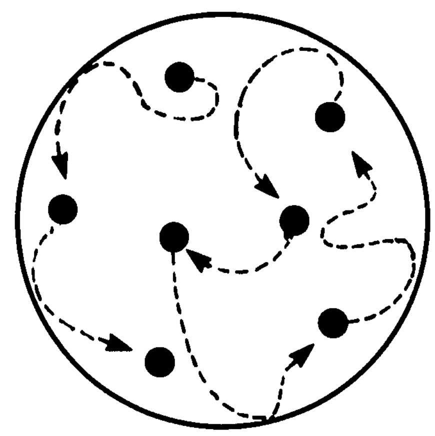


Normally, what is the pleural space?

An air space between the chest wall and lung.	page 16
A space between the parietal and pulmonary pleurae.	page 21
A potential cavity lined by the pleural membranes.	page 26

(from page 26)

YOUR ANSWER: This diagram shows molecules exerting pressure on the walls of a container:

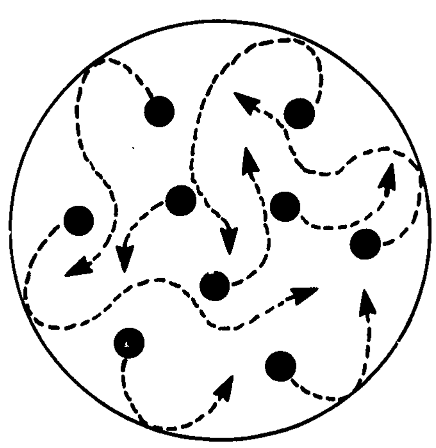


Right. These tiny particles move continually and their collision with confining boundaries creates pressure.

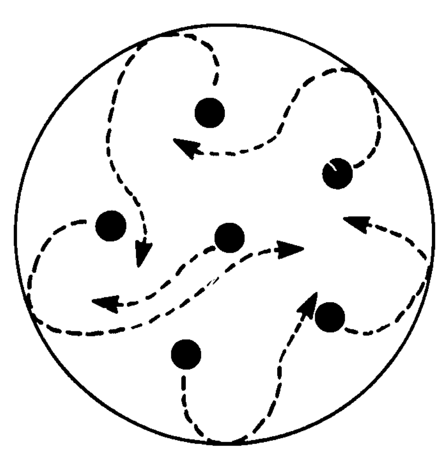
Several factors influence the amount of pressure present in any given space. One of these factors is the concentration of the molecules.

A greater number of molecules moving in a certain amount of space creates a greater degree of pressure than fewer molecules moving in the same amount of space. The reason for this is clear: Large numbers of molecules within a space bombard the confining walls of that space more frequently than do a few molecules within the same space.

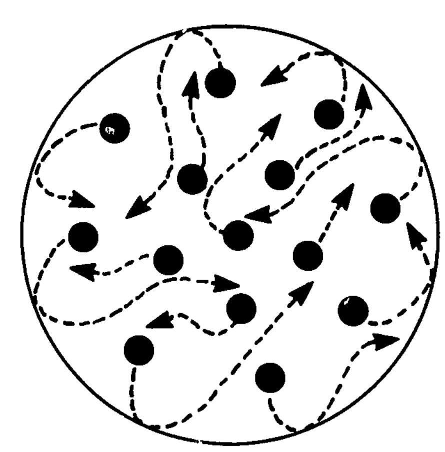
Each of the three circles below encloses the same quantity of space; select the one which represents the greatest degree of pressure:



page 27



page 30



page 33

YOUR ANSWER: If atmospheric pressure atop Mount Whitney (14,495 feet) were 700 mm. of mercury, 690 mm. would be negative pressure at that altitude.

Right you are. Any degree of pressure *less* than that in the atmosphere is called "negative pressure."

Negative pressure is a partial vacuum. (An absolute vacuum would be complete absence of pressure, which we've just said doesn't exist on earth.)

Being a vacuum, negative pressure has a sucking or pulling effect. Conversely, we might say that positive pressure has a blowing or pushing effect.

These two effects may appear to be unrelated but, in fact, they are interdependent. When we talk about normal respiration, which will be soon, we'll explain this interrelationship.

Which of the alternatives below correctly completes the following statement? Pressure which is less than atmospheric:

Creates an absolute vacuum.	page 34
Exerts a pushing force.	page 37
Exerts a suctioning force.	page 40

YOUR ANSWER: Normally, the pleural space is a potential cavity lined by the pleural membranes.

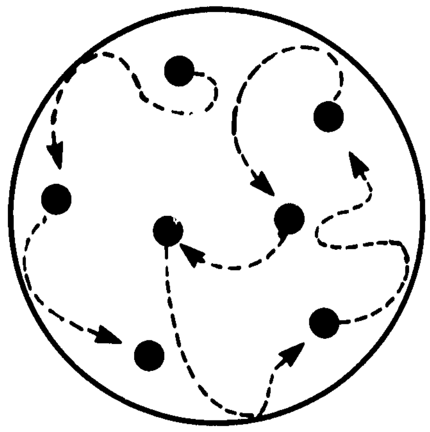
You're right. It is not an actual cavity or space, but it can become one under certain conditions (we'll discuss these later in the course).

We've just pointed out that the pulmonary and parietal pleurae are apposed, i.e., there is no space between them. Now the question is this: What prevents these pleurae from separating? What pulls on the pulmonary pleura, thus keeping the lung extended? This is the same "pulling force" we mentioned earlier; and it is the question about which we said there are various theories.

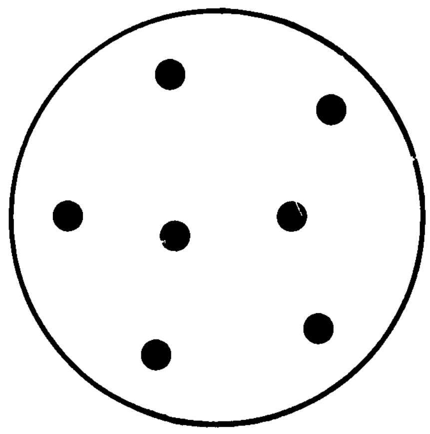
As part of our explanation of this phenomenon, let's discuss a few important ideas about pressure. First, let's consider this: *Pressure is created by the movement of tiny particles known as molecules.*

No doubt you already know that all substance (whether in a solid, liquid, or gaseous state) is composed of molecules which are continually in motion. In a solid substance, molecules are bound together and cannot travel far. In liquid and air, molecules travel more freely, bouncing into each other and into other surfaces (such as the walls of a container). It is the collision of these tiny particles which creates pressure.

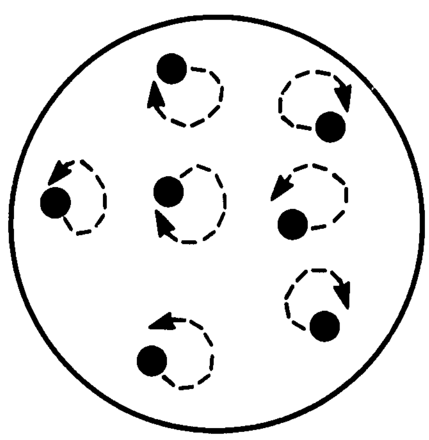
Which of the following diagrams shows molecules exerting pressure on the walls of a container?



page 24

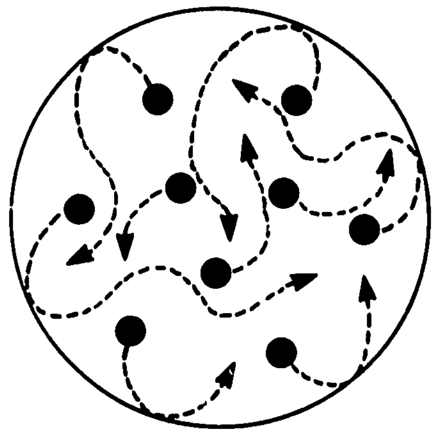


page 28



page 31

YOUR ANSWER: This circle represents the greatest degree of pressure:

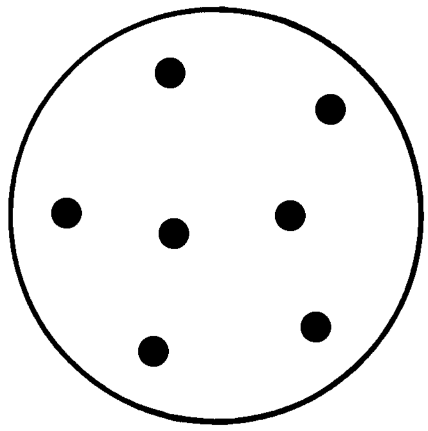


Wrong.

Remember that the greater the concentration of molecules, the greater the pressure.

RETURN to page 24 and select the circle with the greatest concentration of molecules.

YOUR ANSWER: This diagram shows molecules exerting pressure on the walls of a container:



No.

In the diagram you chose, the molecules appear to be standing still—which never happens. The molecules of all substances are continually in motion.

It is hard to believe that the molecules of an iron bar, for example, are moving. However, this theory (the Kinetic Molecular Theory of Matter) is widely accepted by physicists. In a solid, such as an iron bar, molecules move within a lattice structure, vibrating back and forth in a small area.

In liquid and air, molecules move more freely; they bump into each other as well as into the confining boundaries they meet.

Please RETURN to page 26 and select the correct answer.

The degree of pressure in the atmosphere varies, depending for one thing on altitude. At sea level, for example, atmospheric pressure generally is 760 mm. of mercury; but it is considerably less than that on top of a 10,000-foot mountain. The effects of gravity are important influences on atmospheric pressure.

Degrees of pressure which are less than the pressure in the atmosphere are called subatmospheric or *negative* pressure.

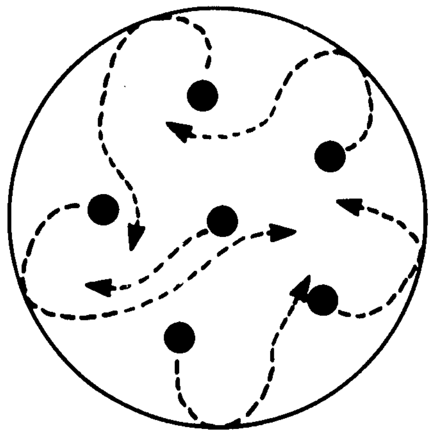
The latter term (negative pressure) is somewhat misleading, since the word "negative" is often interpreted as meaning "no." "Negative pressure" therefore sounds as if it means "no pressure." This of course is not its meaning; a complete absence of pressure does not exist on earth. Instead, "negative pressure" refers to a degree of pressure which is less than that in the atmosphere.

Now answer this question: If the pressure in the atmosphere atop Mount Whitney (14,495 feet above sea level) were 700 mm. of mercury, which of the following would be negative pressure at that altitude?

690 mm. of mercury.	page 25
710 mm. of mercury.	page 32
700 mm. of mercury.	page 35

(from page 24)

YOUR ANSWER: This circle represents the greatest degree of pressure:

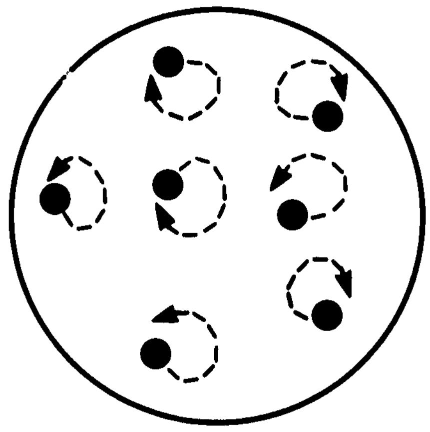


Wrong.

Remember that the greater the concentration of molecules, the greater the pressure. The greater the number of molecules moving within a space, the more frequent are their bombardments of the walls of that space.

RETURN to page 24 and select the circle with the greatest concentration of molecules.

YOUR ANSWER: This diagram shows molecules exerting pressure on the walls of a container:



Not exactly.

The molecules in the diagram you chose appear to be going around in circles, don't they? This is not exactly what happens.

It's true that molecules in all substances move continually. However, their movement makes them collide in a random fashion. They may bump into each other or into the confining boundaries they meet.

Please RETURN to page 26 and select the correct answer.

YOUR ANSWER: If atmospheric pressure atop Mount Whitney (14,495 feet) were 700 mm. of mercury, 710 mm. would be negative pressure at that altitude.

Wrong.

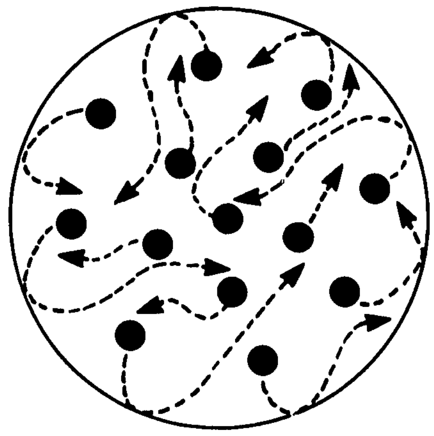
The figure you chose is greater than our hypothetical atmospheric pressure; therefore it would represent positive pressure.

Remember that the term "negative pressure" describes any degree of pressure which is *less* than that in the atmosphere. Remember also that one would have to travel to outer space to find an absolute lack of pressure.

Please RETURN to page 29 and choose the correct answer.

57

YOUR ANSWER: This circle represents the greatest degree of pressure:



Correct. More molecules are moving in this circle; therefore bombardment of the confining walls of the space is more frequent.

In this course, we're concerned with the pressure of liquid and air, and especially that of air. As you know, air (the atmosphere) is made up of gases and the degree of pressure created by these gases is measurable.

The pressure of gases in the air is called *atmospheric* pressure. Any degree of pressure *higher* than the pressure in the atmosphere is called *positive* pressure.

Note: Although atmospheric pressure also is called positive pressure, in this course "positive pressure" will refer only to pressure greater than that in the atmosphere.

Please turn to page 29.

(from page 25)

YOUR ANSWER: Pressure which is less than atmospheric creates an absolute vacuum.

Not true.

An absolute vacuum would be an absolute *absence* of pressure, a situation which we've noted doesn't exist on earth.

Apparently our explanation of negative pressure wasn't quite clear to you. This *is* a misleading term because it seems to say "no pressure." This is not, however, its meaning. Any degree of pressure which is less than the pressure in the atmosphere is known as "negative pressure." In other words, if atmospheric pressure were 700 mm. of mercury, 699 mm. would be negative pressure.

Since negative pressure is a partial vacuum, it has a sucking or pulling effect. You know the effect that a vacuum cleaner has on a carpet; its sucking action is due to negative pressure created by a motor.

Now RETURN to page 25 and select the correct alternative.

(from page 29)

YOUR ANSWER: If atmospheric pressure atop Mount Whitney (14,495 feet) were 700 mm. of mercury, that would be negative pressure at that altitude.

No, you haven't understood the definition of negative pressure.

Remember that the term "negative pressure" describes any degree of pressure which is *less* than that in the atmosphere.

Atmospheric pressure can vary, depending for one thing on altitude. Since our hypothetical atmospheric pressure (atop Mount Whitney) is 700 mm. of mercury, negative pressure at that altitude would have to be a figure less than 700.

Please RETURN to page 29 and choose the correct answer.

(from page 40)

YOUR ANSWER: Elasticity probably holds Mr. Marlin's lungs in an expanded position.

Wrong.

It's because of the elastic nature of the lung tissue that it has a tendency to recoil or collapse. You'll remember that we compared the elastic fibers of the lungs to rubber bands which recoil when released from being stretched.

To overcome this recoil tendency, there must be a pulling force which holds the lung in expansion. Negative pressure within the airtight pleural space appears to have the effect of holding the pulmonary and parietal pleurae in apposition, thus maintaining the lung in expansion.

Please RETURN to page 40 and choose the correct answer.

YOUR ANSWER: Pressure which is less than atmospheric exerts a pushing force.

No.

The alternative you chose describes the effect of positive pressure.

Remember this now: A pressure greater than that in the atmosphere is called *positive* pressure; pressure less than that in the atmosphere is called *negative* pressure.

To put it another way: Suppose that atmospheric pressure were 700 mm. of mercury. Then, 699 mm., 698, 697, etc., would be negative pressure.

Since negative pressure is a partial vacuum, it has a sucking or pulling effect. You know the effect that a vacuum cleaner has on a carpet; its sucking action is due to negative pressure created by a motor.

Please RETURN to page 25 and select the correct alternative.

YOUR ANSWER: Negative pressure probably holds Mr. Marlin's lungs in an expanded position.

Correct.

Negative pressure is probably not the only factor involved, but it appears that its suctioning effect contributes to the continuous expansion of the lung. (Note: This is one of the theories we mentioned earlier. And although it is believed that the negative intrapleural pressure may be a result, rather than the cause, of the lung following the chest wall, for our purposes we have chosen to explain the situation in this manner.)

Another factor which probably contributes to holding the pulmonary and parietal pleurae in apposition concerns the thin film of serous fluid which is present in the pleural space. The presence of this fluid results in cohesion of the two membranes. "Like" molecules are attracted to each other, and this attraction results in "tensile strength" which makes the moist pleural membranes stick to each other.

Although we will not explain tensile strength in detail in this course, here's an example of its effect: If you have tried to separate two glass slides which have a drop or two of water between them, you know that it's very difficult to pull them apart. Tensile strength holds the slides together.

The intrapleural fluid also acts as a lubricant, permitting the two pleurae to glide over one another during respiration.

Which of the following probably holds Mr. Marlin's lungs in an expanded position?

Cohesion.	page 41
Apposition.	page 44
Lubrication.	page 46

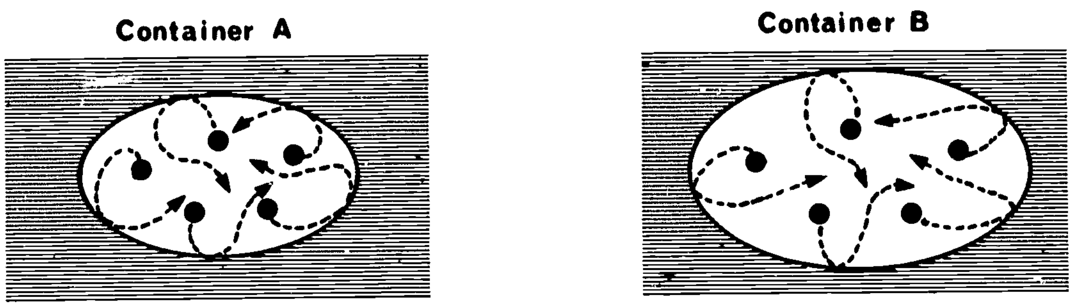
(from page 41 or 49)

Next we're going to consider a few points about Mr. Marlin's normal respiratory process. To understand certain aspects of the normal respiratory process, we should discuss a few more ideas about pressure. Let's do that now.

Remember we said that pressure is created by the collision of minute particles called molecules against a surface. Remember also that these molecules are continuously in motion. If temperature is constant, they move at a constant rate of speed.

Here is an important idea: Increasing the size of the space within which molecules are confined lowers the amount of pressure within that space, and vice versa.

To illustrate, let's look at an imaginary five molecules, confined first in a small container (A) and then in a larger one (B):



Notice that the five molecules in Container A are close together; they will collide with the walls of the container frequently. In Container B, our five molecules are farther apart; they will strike the walls of the container less often.

Now suppose that the pressure in Container A is 50. Which of the following numbers could represent the pressure in Container B?

55	page 42
50	page 45
40	page 51

(from page 25)

YOUR ANSWER: Pressure which is less than atmospheric exerts a suctioning force.

You're right. Negative pressure is a partial vacuum and has a sucking effect.

It may seem that we've digressed quite a bit from our patient, Mr. Marlin, but we haven't forgotten him. In fact, we now have one explanation for a question we raised a while back, namely: What prevents his pulmonary and parietal pleurae from separating?

It appears that one factor which helps to keep these pleurae in apposition is negative pressure. Pressure within the closed pleural space is always negative during normal respiration.

Since negative (subatmospheric) pressure is a partial vacuum and therefore has a suctioning effect, it appears likely that this effect contributes to the continuous extension of the elastic lung tissue.

You'll recall that we compared the elastic fibers of the lungs to rubber bands which recoil when released from being stretched. In order to hold the lungs in a constantly expanded position, it is necessary to overpower this tendency to recoil.

Which of the following probably holds Mr. Marlin's lungs in an expanded position?

Elasticity.	page 36
Negative pressure.	page 38
A tendency to recoil.	page 43

YOUR ANSWER: Cohesion probably holds Mr. Marlin's lungs in an expanded position.

Right.

The thin film of fluid in the pleural space probably has the effect of making the moist pulmonary and parietal membranes stick to each other, thus holding the lung in expansion. (This is another of the theories we mentioned before.)

Now, we're almost ready to talk about normal respiration. Before we do, however, let's repeat some of the important ideas we've covered so far:

a. Each lung is contained within an airtight cavity (pleural space).
b. Lung tissue is elastic and has the capacity to recoil.
c. All substance (matter) has a measurable degree of pressure.
d. Negative (subatmospheric) pressure has a suctioning effect.
e. Intrapleural pressure is always negative during normal respiration.
f. There is a small quantity of fluid between the pulmonary and parietal pleurae.
g. The moist pulmonary and parietal membranes are cohesive.

All of the above are factors which appear to contribute to the continuous expansion of Mr. Marlin's lungs.

We are sure you know that there certainly are other factors which play a part too. In fact, respiration is an extremely complex interplay of many more factors than we are discussing in this course. But since our purpose is to provide a certain degree of understanding which is relevant to closed drainage of the chest, we shall not attempt to cover all of the details of the situation.

If you wish to read the comments of several authors concerning reasons for the continuous expansion of the lungs, please turn to page 47. If you prefer to go on without reading these comments, please turn to page 39.

(from page 39)

YOUR ANSWER: The number 55 could represent the pressure in Container B.

Wrong. Not if the pressure in Container A is 50.

If the number of molecules within a container is constant, increasing the size of the container lowers the pressure in that container. Of course the opposite is true also: Reducing the capacity of the container increases the pressure.

The reason that the amount of pressure changes as the capacity of the container changes is this: Given a constant temperature (which results in a constant rate of movement), the same number of molecules travels much farther to strike the walls of the large container than to collide with the walls of the smaller container. In the larger container, they bombard the walls less frequently and, therefore, create less pressure.

Please RETURN to page 39 and look at the diagrams again before selecting the right answer.

(from page 40)

YOUR ANSWER: A tendency to recoil probably holds Mr. Marlin's lungs in an expanded position.

Wrong.

You are right that the elastic fibers of the lungs recoil when released from being stretched. To overcome this recoil tendency, there must be a pulling force which holds these fibers in an extended position.

Since the negative pressure within the airtight pleural space has a suctioning effect, it appears that this effect plays a part in holding the pulmonary and parietal pleurae in apposition, thus maintaining the lung in expansion.

Please RETURN to page 40 and choose the correct answer.

(from page 38)

YOUR ANSWER: Apposition probably holds Mr. Marlin's lungs in an expanded position.

No.

We've been discussing reasons that the pulmonary and parietal pleurae are held in apposition, i.e., next to each other with no space between. The fact that they are apposed is not in itself a reason for this situation.

One of the reasons that these pleurae remain continuously in apposition (thus holding the lung in expansion) concerns the thin film of fluid which is in the pleural space. The fluid makes the two moist pleural membranes stick together.

Please RETURN to page 38 and choose a better answer.

YOUR ANSWER: The number 50 could represent the pressure in Container B.

Wrong.

Not if the pressure in Container A is 50.

Apparently you haven't understood that the size of the container has an effect on the amount of pressure within it.

Let's go over it again. The reason that the amount of pressure changes as the capacity of the container changes is this: Given a constant number of molecules and constant temperature (which results in a constant rate of movement), the molecules travel much farther to strike the walls of the larger container than to collide with the walls of the smaller container. In the larger container, they bombard the walls less frequently and, therefore, create less pressure.

Remember this: Increasing the capacity of the container lowers the pressure; reducing the capacity of the container increases the pressure.

Please RETURN to page 39 and look at the diagrams again before selecting the right answer.

YOUR ANSWER: Lubrication probably holds Mr. Marlin's lungs in an expanded position.

Not exactly.

The thin film of fluid in the pleural space does act as a lubricant. It permits the pulmonary and parietal pleurae to glide over one another without friction during respiration. The fact that these membranes are lubricated is not, however, a reason that they are held in apposition.

Aside from acting as a lubricant, the fluid in the pleural space has the effect of making the two moist pleural membranes stick together.

Please RETURN to page 38 and select a better answer.

The following are quotations from several authors concerning reasons for the continuous expansion of the lungs:

". . . the lung is maintained in an inflated condition by the weight (pressure) of atmospheric air through the open respiratory tract while it is held in apposition to the chest wall by the intrapleural pressure which is less than the atmospheric pressure. This state is referred to sometimes as a partial vacuum . . . The centrifugal traction force of the intrapleural negative pressure holds the lung in apposition to the chest wall."

Banyai, A. L.: Collapse of the Lung, in Clinical Cardiopulmonary Physiology, Sponsored by the American College of Chest Physicians, New York, Grune & Stratton, 1960, ed. 2.

* * *

"The visceral and parietal pleurae being inseparable the lungs follow the thoracic wall as it enlarges, and therefore must expand . . . The lung throughout the individual's life remains in the expanded position—pressed as it were against the thoracic framework as a result of the greater pressure exerted upon the alveolar than upon the pleural aspects of the pulmonary tissue . . . Another and apparently a more important factor in preventing the separation of the pleural surfaces, and maintaining the lungs normally in the expanded state against their own elastic pull, is the 'hydraulic traction' (West) exerted by the film of fluid between the layers of the pleura . . . inequality of pressure on the two sides of the two aspects of the lung is not the sole, nor perhaps the most important, factor holding the pleural layers in close apposition . . ."

Best, C. H. and Taylor, N. B.: The Physiological Basis of Medical Practice, Baltimore, The Williams & Wilkins Company, 1961, ed. 7.

* * *

". . . the cohesion between the two pleural layers (due to the thin film of pleural fluid) is very great, and separation normally does not occur. Instead, the visceral pleura, and the elastic lung to which it is attached, expand with the enlarging thoracic cavity."

Chaffee, E. E. and Greisheimer, E. M.: Basic Physiology and Anatomy, Philadelphia, J. B. Lippincott Company, 1964.

Please turn to page 48.

Here are additional explanations:

"The lungs are held out against the chest wall by the atmospheric pressure, which is being applied both at the surface of the body as well as within the lungs."

Cherniack, R. M. and Cherniack, L.: Respiration in Health and Disease, Philadelphia, W. B. Saunders Company, 1961.

* * *

". . . the lungs *and* thoracic cage, held *together* normally by the pleural surfaces . . ."

Comroe, J. H., Jr., and others: The Lung; Clinical Physiology and Pulmonary Function Tests, Chicago, Year Book Medical Publishers, Inc., 1962, ed. 2.

* * *

"Normally, intrapleural pressure is slightly below atmospheric pressure. It is the presence of this partial vacuum within the thorax that maintains the lungs in their constantly expanded state."

Johnson, J. and Kirby, C. K.: Surgery of the Chest; A Handbook of Operative Surgery, Chicago, The Year Book Publishers, Inc., 1952.

* * *

"Finally, a comment on the venerable question: What holds the lungs against the chest wall? One view, which in the writer's opinion is adequate, is to regard occupancy of the chest cavity as a comp tition between solids, liquids, and gases. The liquids are removed down to a vestige because the capillary pressure in the visceral pleura is considerably lower than its colloid osmotic pressure, a matter first brought forth and beautifully elucidated by Agostoni and co-workers(2). The gases are removed, as Fenn(105) and others have pointed out, because the total gas pressure in venous capillary blood is considerably less than atmospheric due to the relative capacity of the blood for carbon dioxide and oxygen. The lungs, chest wall, and diaphragm are then pressed into service by atmospheric pressure and occupy the space, as it were, by default."

Mead, J.: Mechanical Properties of Lungs, Physiol. Rev. *41*:281 (Apr.) 1961.

Please turn to page 49.

Here are additional explanations:

"The pleural surfaces of the lung are intimately applied to the inner pleural surfaces of the thoracic cavity and held there by atmospheric pressure, less recoil pressures of the lung and thorax. Only a thin film of lymph is interposed between these two surfaces to form a potential pleural space, and because of the firm and intimate contact, the shape and volume of the lung must conform to that of its thoracic container . . . The pull holding chest and lungs together is manifest as negative intrapleural pressure . . ."

Miller, W. F., Johnson, R. L., Jr., and Cushing, I. E.: Mechanics of Breathing, in Clinical Cardiopulmonary Physiology, Sponsored by the American College of Chest Physicians, New York, Grune & Stratton, 1960, ed. 2.

* * *

"The intrapleural lymph is under tension, and, like all liquids, has considerable tensile strength (intermolecular attractive forces) and is fully capable of holding the lungs expanded even during the greatest possible stresses exerted physiologically."

Nims, L. F.: Anatomy and Physics of Respiration, in Fulton, J. F.: A Textbook of Physiology, Philadelphia, W. B. Saunders Company, 1955, ed. 17.

* * *

". . . a certain negative intrapleural pressure is required to overcome them (the elastic forces) throughout respiration—during inspiration, to expand the lung; during expiration, to retard excessive elastic collapse of the lung."

Rossier, P. H., Buhlmann, A. A., and Wiesinger, K.: Respiration; Physiologic Principles and their Clinical Applications, translated into English and edited by P. C. Luchsinger and K. M. Moser, St. Louis, The C. V. Mosby Company, 1960.

* * *

"Pressure also keeps the lungs inflated because the space surrounding the lungs (the pleural cavity) is at a slightly lower pressure than the lungs themselves; the higher pressure in the lungs keeps them inflated."

Sackheim, G. I.: Practical Physics for Nurses, Philadelphia, W. B. Saunders Company, 1962, ed. 2.

To go on with the course, turn to page 39.

2

(from page 55)

YOUR ANSWER: The number 710 could represent Mr. Marlin's intrapulmonary pressure during inspiration.

No.

We said that his intrapulmonary pressure *before* inspiration is 710. And your choice indicates that you think his intrapulmonary pressure wouldn't change during inspiration.

Remember this! Pressure within a container decreases as the capacity of the container increases.

In applying this idea, we found that intrapleural pressure decreases on inspiration, because the capacity of the pleural space increases along with expansion of the thoracic cavity.

The same principle applies to intrapulmonary pressure. On inspiration, the capacity of the lung increases—and intrapulmonary pressure falls.

Please RETURN now to page 55 and choose the correct answer.

(from page 39)

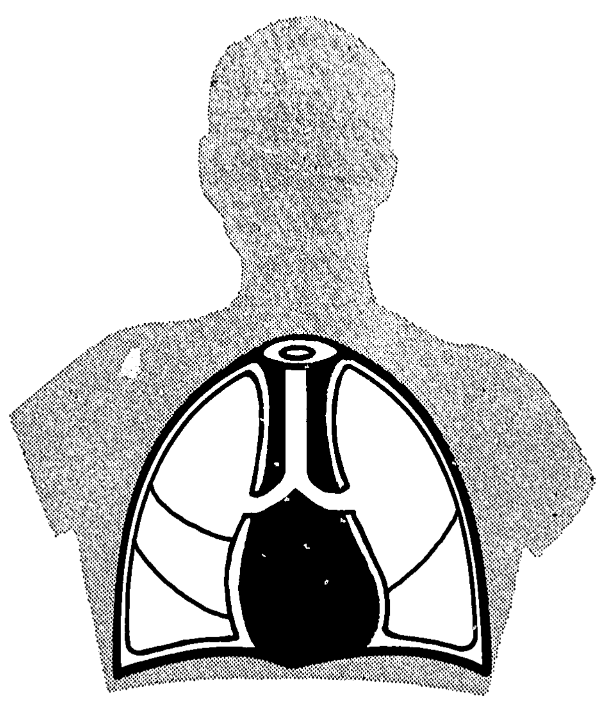
YOUR ANSWER: The number 40 could represent the pressure in Container B.

Right. If the temperature is constant (resulting in a constant *rate* of movement), our five molecules create less pressure in a larger container.

Now let's apply this idea to Mr. Marlin. (Remembering that the pleural space or cavity is similar to a closed container may help you to understand the next point.)

Here's what happens when Mr. Marlin inhales: His diaphragm contracts, pulling downward; and his chest muscles pull the chest wall up and out. These muscular actions enlarge his thoracic cavity, both vertically and horizontally (observe yourself as you inhale). As Mr. Marlin's thoracic cavity enlarges, his pleural spaces likewise become larger. Compare the two diagrams below:

CHEST 'AT REST'



INSPIRATION

Now what do you think happens to his intrapleural pressure during Mr. Marlin's inspiration? It:

Increases. page 53
Decreases. page 55
Is unchanged. page 57

(from page 55)

YOUR ANSWER: The number 720 could represent Mr. Marlin's intrapulmonary pressure during inspiration.

Not if this pressure is 710 before inspiration.

Remember that on inspiration, the capacity of the lung increases. If we think of the lung as a container, we can conclude that the same change in pressure occurs within the lung during inspiration as within the pleural space.

This is not to say that intrapulmonary pressure and intrapleural pressure would be the same; pressure within the pleural space is *always* negative during normal respiration, whereas pressure within the lung is sometimes positive, as we'll discover in a moment.

The point is this: Increasing the capacity of the container causes the pressure within that container to fall.

Now please RETURN to page 55 and select the correct answer.

(from page 51)

YOUR ANSWER: During inspiration, Mr. Marlin's intrapleural pressure increases.

Wrong.

Earlier in the course we pointed out that the pleural space is similar to a closed sac or container. And we have just discussed the fact that increasing the size of a container lowers the pressure within it.

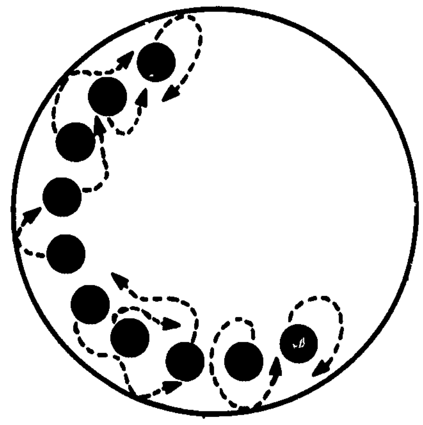
Remember that the increased size results in less frequent bombardment by the molecules within the container. (They must travel farther and, therefore, strike the surfaces of the container less often.)

Think of the pleural space as a container whose capacity increases as the thoracic cavity enlarges.

RETURN to page 51 and select the right answer.

(from page 58)

YOUR ANSWER: This diagram illustrates equilibrium (equal pressure in all directions):



Wrong.

The diagram you chose shows the molecules lined up along two boundaries instead of distributed within the space.

Characteristically, however, molecules distribute themselves *evenly* in a space. Because of this even distribution of molecules, pressure is "balanced" and a state of equilibrium is produced.

Please RETURN to page 58 and select the diagram which shows even distribution of the molecules.

YOUR ANSWER: During inspiration, Mr. Marlin's intrapleural pressure decreases.

Very good. You were able to apply the idea that pressure decreases as the capacity of the container increases. Keep that idea in mind as we go on. (Note: Although we have chosen to explain the normal changes in intrapleural pressure in this manner, we do want to mention that other important factors are concerned also. One of these involves the inward pull of the elastic lungs trying to resist the outward expansion of the chest wall.)

We already know that Mr. Marlin's intrapleural pressure is always negative (subatmospheric) during normal respiration. On inspiration, then, this pressure falls even lower, farther below that of the atmosphere.

The lower Mr. Marlin's intrapleural pressure falls, the greater the suctioning effect it has (since the strength of this effect is related to the "negativeness" of the pressure).

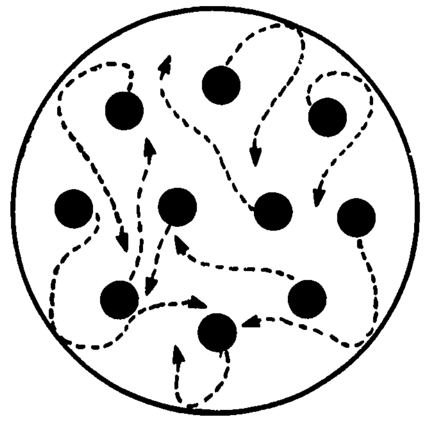
As Mr. Marlin's thoracic cavity enlarges, his lungs remain continuously in apposition to the chest wall. This has the effect of increasing the size (and capacity) of his lungs.

Now think of the lung as a container. Suppose that the pressure within Mr. Marlin's lungs before inspiration is 710. Which of the following could represent his intrapulmonary pressure during inspiration?

710	page 50
720	page 52
700	page 58

(from page 58)

YOUR ANSWER: This diagram illustrates equilibrium (equal pressure in all directions):



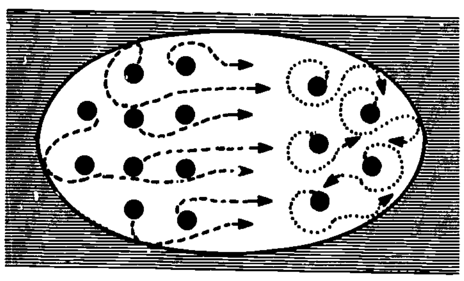
Right! Molecules distribute themselves equally within a space, the result being equal pressure in all directions.

Here's what happens because of this characteristic movement to equalize pressure: When two areas of unequal pressure are in contact, molecules move from the area of greater pressure to the area of lesser pressure.

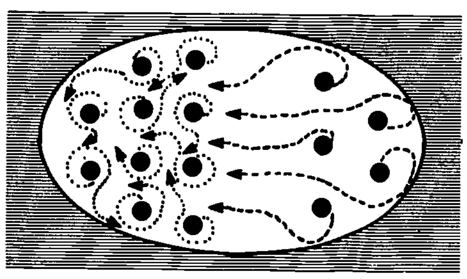
For example, differences in pressure are responsible in part for changes in the weather. When atmospheric pressure falls rapidly, a wind will begin to blow. This wind represents the movement of air from an adjacent high pressure area into the low pressure area.

We could say the low pressure area *sucks* molecules from the adjacent high pressure area—or that the high pressure area *blows* molecules into the low pressure area (and this is the interrelationship of effects of negative and positive pressures we spoke of earlier). No matter how we express it, this movement from greater to lower pressure is due to the characteristic action of molecules to distribute themselves evenly in a space.

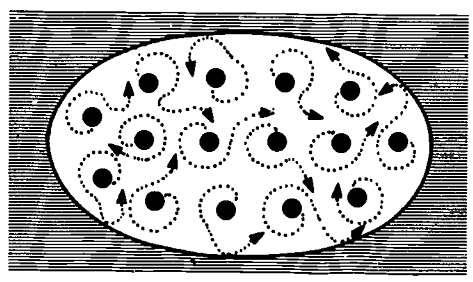
Choose the diagram which represents molecules moving from a high to a low pressure area in order to distribute themselves evenly:



page 64



page 66



page 69

YOUR ANSWER: During inspiration, Mr. Marlin's intrapleural pressure is unchanged.

No, you've missed the point.

Think of the pleural space as a closed container. And remember we've just discussed the fact that increasing the capacity of a container lowers the pressure within it. (The increase in size results in less frequent bombardment by the molecules within the container. They must travel farther and, therefore, strike the surfaces of the container less often.)

On inspiration, the capacity of the pleural space increases as a result of the enlargement of the thoracic cavity.

RETURN to page 51; look at the diagrams again; and then choose the correct answer.

(from page 55)

YOUR ANSWER: The number 700 could represent Mr. Marlin's intrapulmonary pressure during inspiration.

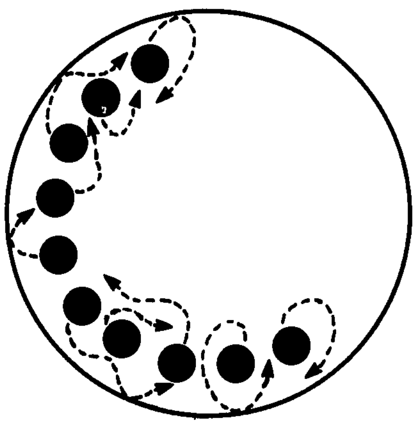
Correct. The same principle applies: Increasing the capacity of the lung causes the pressure within the lung to fall.

Now let's consider another fact about pressure: Characteristically, molecules distribute themselves evenly in a space. The result of this movement is equalization of pressure within that space.

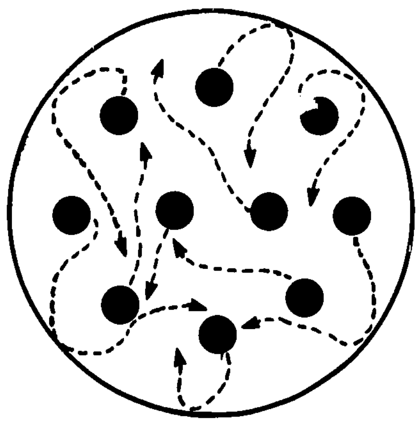
The movement of the molecules is called *diffusion;* and the state of being evenly distributed is called *equilibrium.*

We can say then that equilibrium is attained when there is the same amount of pressure in all directions.

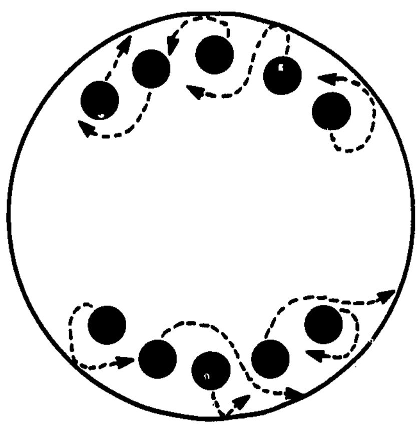
Decide which of the following diagrams illustrates equilibrium (equal pressure in all directions):



page 54



page 56



page 63

(from page 71)

OPTIONAL REVIEW OF SECTION I

This review is based on the important background information contained in the first section of the course.

If you're beginning the course with Section II, you may find this review useful to help you determine whether it would be well for you to study the first part of the course, or whether you already have a thorough understanding of the ideas it contains.

If you have already studied Section I, you may wish to take this review to make certain you've understood the pertinent concepts we've covered.

If you wish to take the review, go to page 60. If you want to skip it, go on to page 78.

(from page 59)

OPTIONAL REVIEW OF SECTION I

In this review, you will have a choice of words with which to fill in the blanks. On a piece of paper, write down the number of the question and your choice of answers.

1. Each lung chamber is ———.
   (a) airtight (b) elongated (c) small

2. The outer boundaries of the thoracic cavity are the ———, ———, and ———.
   (a) diaphragm (d) heart
   (b) lungs (e) superior mediastinum
   (c) chest wall (f) trachea

3. The pulmonary and parietal pleurae ———.
   (a) line the trachea
   (b) form a closed sac
   (c) enclose the heart and aorta

4. Normally, each lung is extended to fill ——— of the available space.
   (a) all (b) part (c) one-half

5. The greater the concentration of molecules in a given space, the ——— the pressure within the space.
   (a) greater (b) same (c) lesser

6. Molecules create pressure by ———.
   (a) whirling in circles
   (b) colliding with a surface
   (c) remaining in a fixed position

Turn to page 61.

7. The pleural space is ———.
   (a) a potential cavity
   (b) located within the lung
   (c) another name for bronchus

8. A ——— force maintains the lungs in an extended position.
   (a) pushing (b) blowing (c) pulling

9. Each lung occupies its own ——— cavity.
   (a) open (b) closed (c) divided

10. Increasing the capacity of a container ——— the pressure within that container.
    (a) levels (b) raises (c) lowers

11. During inspiration, intrapulmonary pressure ———.
    (a) falls (b) rises (c) remains unchanged

12. During inspiration, intrapleural pressure ———.
    (a) falls (b) rises (c) remains unchanged

13. Negative pressure has a ——— effect.
    (a) blowing (b) sucking (c) pushing

14. Positive pressure refers to pressure which is ———.
    (a) atmospheric or less
    (b) less than atmospheric
    (c) greater than atmospheric

15. During inspiration, ——— causes air to move into the lungs.
    (a) decreased atmospheric pressure
    (b) inequality of pressure
    (c) equalized pressure

Turn to page 62.

(from page 61)

16. During expiration, ——— causes air to move out of the lungs.
    (a) decreased atmospheric pressure
    (b) inequality of pressure
    (c) equalized pressure

17. Within a space, molecules distribute themselves ———.
    (a) haphazardly (b) along one surface (c) evenly

18. Negative pressure refers to pressure which is ———.
    (a) no pressure at all
    (b) less than atmospheric
    (c) atmospheric

19. During expiration, intrapleural and intrapulmonary pressures ———.
    (a) fall (b) rise (c) remain unchanged

20. During normal respiration, pressure within the pleural space is always ———.
    (a) atmospheric (b) negative (c) positive

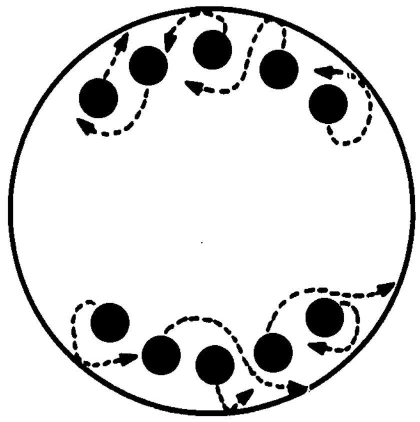
21. Air (or molecules) moves from an area of ——— pressure.
    (a) greater to lesser
    (b) no pressure to some
    (c) lesser to greater

22. The lungs probably are held in an extended position by ———.
    (a) atmospheric pressure within the trachea
    (b) negative pressure within the pleural space
    (c) elastic fibers within lung tissue

23. The lungs probably are held in expansion by ———.
    (a) muscular attachment to the chest wall
    (b) cohesion of the pulmonary and parietal pleurae
    (c) atmospheric pressure in the pleural space

To see how well you did, turn to page 76.

YOUR ANSWER: This diagram illustrates equilibrium (equal pressure in all directions):



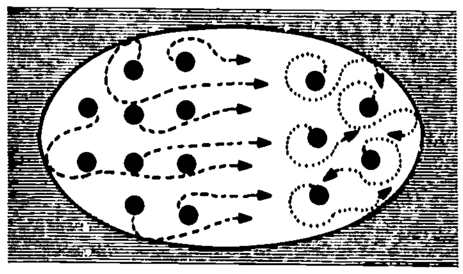
Wrong.

The diagram you chose shows the molecules lined up along opposite boundaries instead of distributed within the space.

The important idea is this: Characteristically, molecules distribute themselves *evenly* in a space. Because of this even distribution of molecules, pressure is "balanced" and a state of equilibrium is produced.

Please RETURN to page 58 and select the diagram which shows even distribution of the molecules.

YOUR ANSWER: This diagram represents molecules moving from a high to a low pressure area in order to distribute themselves evenly:



That's fine! You remembered that the greater the concentration of molecules, the greater the pressure, and the diagram you chose shows molecules moving from the greater to the lesser pressure area.

All right, let's get back to Mr. Marlin's normal respiratory process. We've said that his intrapulmonary capacity increases during inspiration and that this results in a decrease in intrapulmonary pressure.

Suppose that Mr. Marlin's intrapulmonary pressure is 680 and atmospheric pressure is 700. What causes air to move into Mr. Marlin's lungs during inspiration? (Choose the most complete answer.)

Increased intrapulmonary pressure.	page 67
Contraction of the chest muscles.	page 70
Inequality of pressures.	page 72

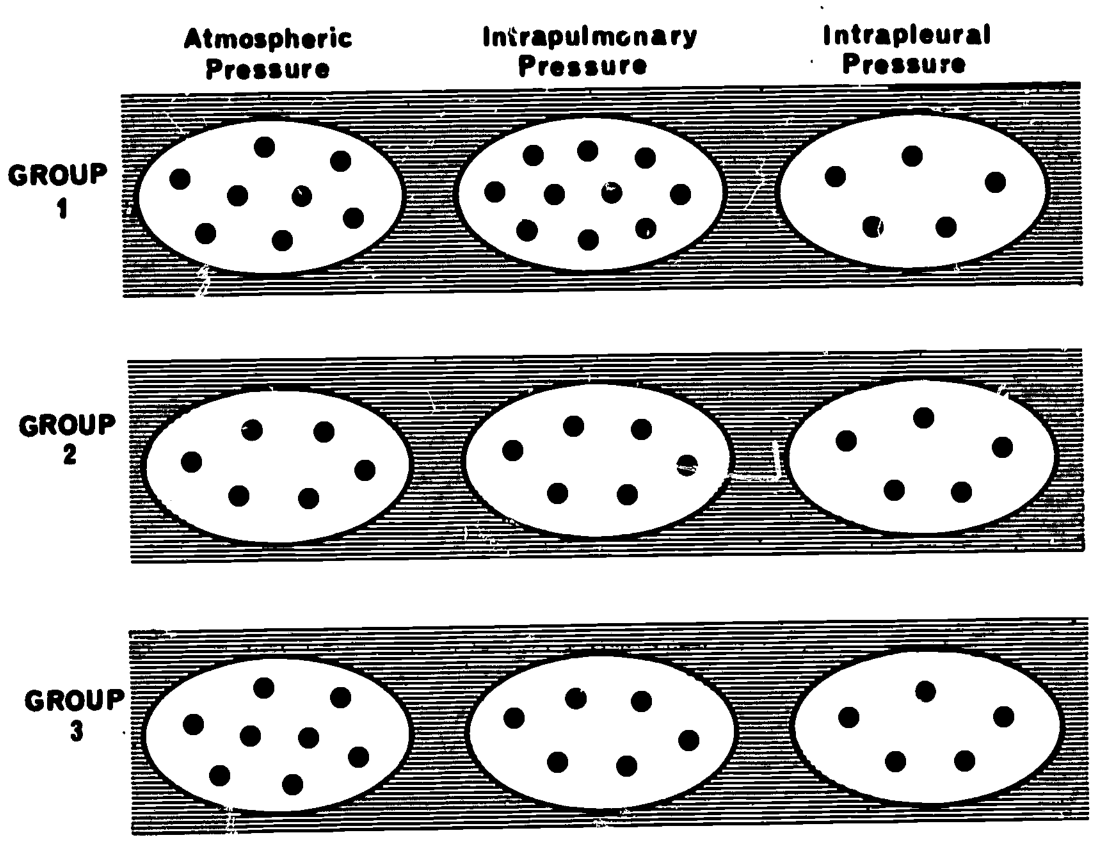
YOUR ANSWER: During Mr. Marlin's expiration, intrapleural and intrapulmonary pressures rise.

Right. As the capacity of these "containers" (his pleural spaces and lungs) decreases, the pressure within them rises.

As we've mentioned before, pressure within the pleural spaces *always* remains negative (subatmospheric). On expiration, it rises to a degree slightly below that of the atmosphere and, therefore, continues to exert enough suction to hold the lungs in apposition to the chest wall.

As the respiratory muscles and lung tissue recoil, pressure within the lungs rises above that of the atmosphere. Again, we have a situation in which two areas of unequal pressure are in contact. Again, molecules move from the area of higher pressure to that of lower pressure. The result is that air moves out of the lung.

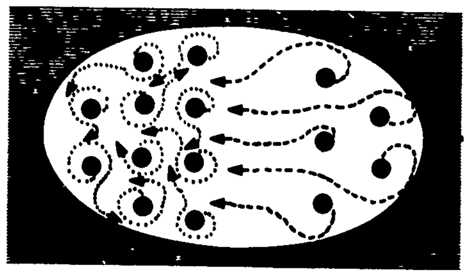
Which of the following three groups of diagrams illustrates the relationship of pressures during expiration?



page 71
page 73
page 75

(from page 56)

YOUR ANSWER: This diagram represents molecules moving from a high to a low pressure area in order to distribute themselves evenly:



Wrong.

Perhaps you've forgotten that the greater the concentration of molecules, the greater the pressure?

The diagram you chose shows molecules moving from an area of lesser pressure toward an area of greater pressure. This is not the way it works.

When two areas of unequal pressure are in contact, molecules move from high to low—from greater to lesser.

Please RETURN to page 56 and select the correct answer.

YOUR ANSWER: Increased intrapulmonary pressure causes air to move into Mr. Marlin's lungs during inspiration.

No.

Intrapulmonary pressure *decreases* during inspiration. Remember that when the capacity of the "container"—in this case, the lung—increases, pressure within the container decreases.

The idea to apply here is that molecules move from an area of greater pressure to an area of lesser pressure.

Remember this very important idea and RETURN to page 64 to select the best answer.

(from page 72)

YOUR ANSWER: During Mr. Marlin's expiration, intrapleural and intrapulmonary pressures fall.

Wrong.

That's what they do during inspiration!

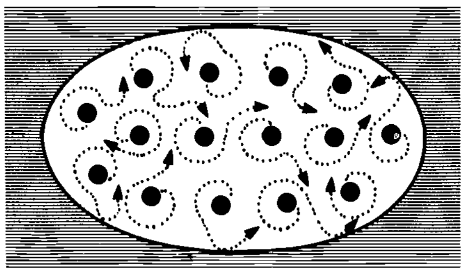
Remember that increasing the size of the space within which molecules are confined lowers the amount of pressure within that space—and vice versa.

During expiration, Mr. Marlin's chest muscles and diaphragm relax and the lungs recoil; the chest cavity grows smaller. As the chest cavity grows smaller, the capacity of the pleural spaces and lungs decreases.

In other words, molecules within these "containers" are crowded closer together and collide with their confining surfaces more frequently.

Please RETURN to page 72 and select the correct answer.

YOUR ANSWER: This diagram represents molecules moving from a high to a low pressure area in order to distribute themselves evenly:



No, the diagram you chose shows an even distribution of molecules.

And remember, when the molecules are evenly distributed, there is equal pressure in all directions.

We've been talking about a change which occurs because of an inequality of pressure. When two areas of unequal pressure are in contact, molecules move from the area of higher pressure to the area of lesser pressure. This movement occurs because of the characteristic action of molecules to distribute themselves evenly in a space.

Now, remembering a point we made earlier—that the greater the concentration of molecules, the greater the pressure—RETURN to page 56 and select the correct answer.

(from page 64)

YOUR ANSWER: Contraction of the chest muscles causes air to move into Mr. Marlin's lungs during inspiration.

Well, we can't say that's wrong. However, it's not the best (most complete) answer.

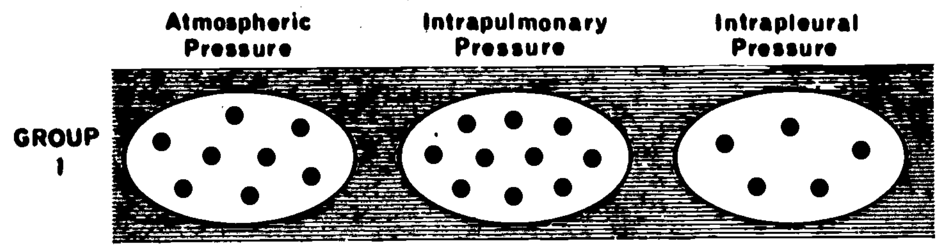
It's true that contraction of the chest muscles, and of the diaphragm, have the effect of increasing the capacity of the lungs, thus lowering the pressure within the lungs. And without this muscular action, normal respiration would be impossible.

The idea we want you to apply here is that molecules move from an area of greater pressure to an area of lesser pressure. This is a very important idea in relation to closed chest drainage.

With this in mind, RETURN to page 64 and select a better answer.

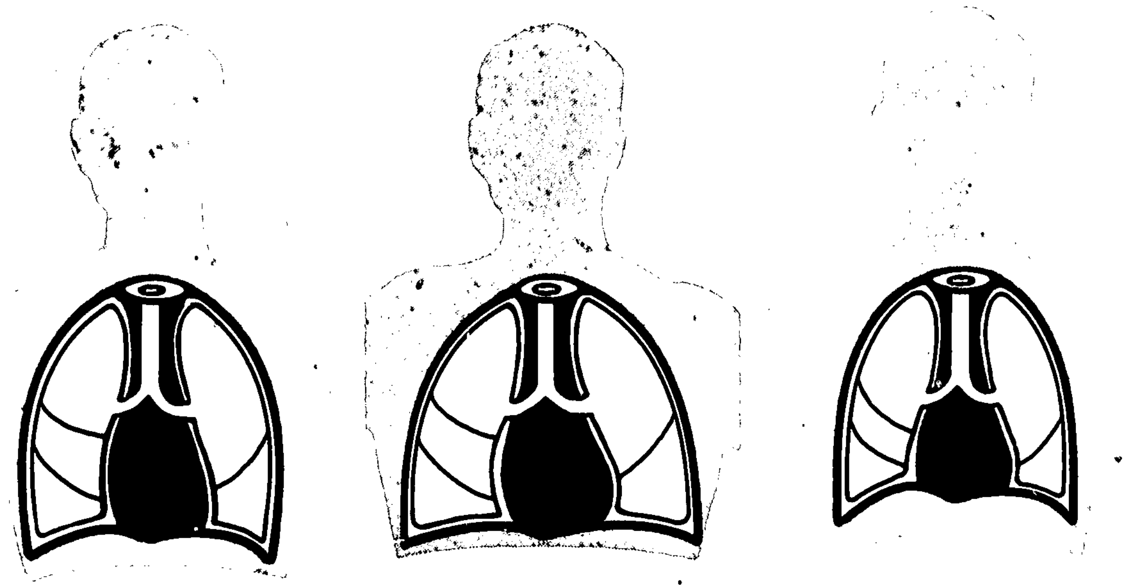
(from page 65)

YOUR ANSWER: This group of diagrams illustrates the relationship of pressures during expiration:



Very good. During expiration, intrapulmonary pressure rises above atmospheric pressure, with the result that air moves out of the lung. Meanwhile, intrapleural pressure is still subatmospheric.

To make certain we have the pressure relationships involved in normal respiration well in mind, let's review by studying the following diagrams and the pressure changes shown below each of them. (These are hypothetical figures.)



	CHEST 'AT REST'	INSPIRATION	EXPIRATION
Atmosphere:	720	720	720
Within lung:	720	717	722
Within pleural space:	716	711	718

This concludes our discussion of normal respiration. Now turn to page 59.

YOUR ANSWER: Inequality of pressures causes air to move into Mr. Marlin's lungs during inspiration.

Yes, that's the answer we hoped you would choose. The important idea is that molecules move from an area of greater pressure to an area of lesser pressure; and that causes air to move into the lungs.

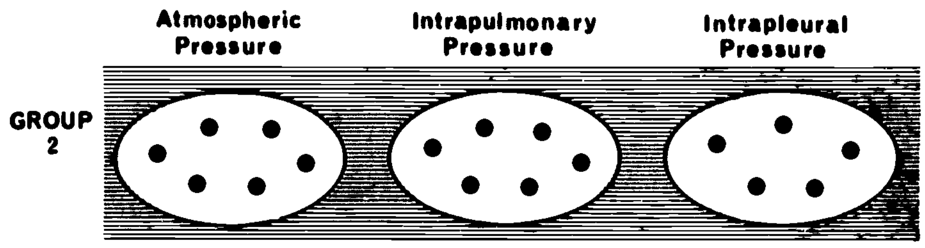
There is, of course, a limit to how much air *can* move into Mr. Marlin's lungs. In normal, passive respiration, the rate and depth of inspiration is regulated by the respiratory center in the brain. Involuntary nerves in the pulmonary pleura signal the respiratory center which, through nerve impulses, halts the inspiratory movement.

Expiration begins. Respiratory muscles relax; the elastic fibers of the lung recoil; the capacity of the pleural and intrapulmonary spaces grows smaller.

Remembering that intrapleural and intrapulmonary pressures fall as the capacity of the pleural spaces and lungs increases, what do you think happens to these pressures during Mr. Marlin's expiration? They:

Rise.	page 65
Fall.	page 68
Are unchanged.	page 74

YOUR ANSWER: This group of diagrams illustrates the relationship of pressures during expiration:



No, it doesn't.

If we had asked you to select the moment between inspiration and expiration, when atmospheric and intrapulmonary pressures are equal, the group of diagrams you chose would be correct. The diagrams you chose *could* represent that situation.

We asked you, however, to choose the group which shows the pressure relationship during expiration. During expiration, intrapulmonary pressure rises *above* atmospheric pressure, while intrapleural pressure, though rising, remains subatmospheric.

Please RETURN to page 65 and select the right answer.

YOUR ANSWER: During Mr. Marlin's expiration, intrapleural and intrapulmonary pressures are unchanged.

Wrong.

Perhaps you've misunderstood; or perhaps we haven't been explaining things clearly. In either case, you're missing something important.

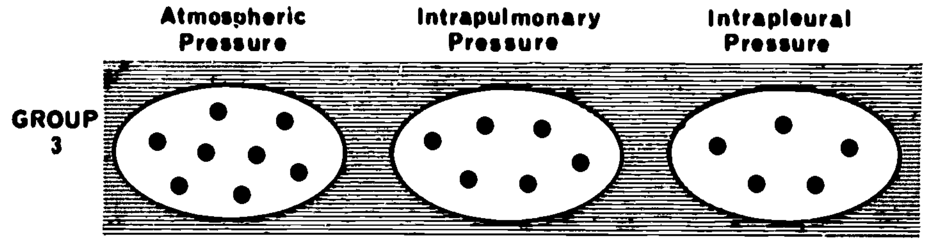
We've been emphasizing changes in pressure so much because these changes are vitally concerned in respiration.

Let's go back to repeat a point we made earlier: increasing the size of the space within which molecules are confined lowers the amount of pressure within that space—and vice versa.

Remember our imaginary five molecules? When we put them in a large container, they were far apart and collided with the walls of the container infrequently. Putting the same five molecules in a smaller container brought them closer together and resulted in more frequent collision with the walls of the container.

Think of Mr. Marlin's pleural spaces and lungs as containers; on expiration these "containers" grow smaller. Now RETURN to page 72 and select the right answer.

YOUR ANSWER: This group of diagrams illustrates the relationship of pressures during expiration:



No.

The group of diagrams you chose could, however, illustrate the situation during inspiration. During inspiration, remember, both intrapulmonary and intrapleural pressures are subatmospheric.

During expiration, intrapulmonary pressure rises above atmospheric pressure, while intrapleural pressure, though rising, remains subatmospheric.

Please RETURN to page 65 and select the right answer.

(from page 62)

Here are the correct answers to the OPTIONAL REVIEW OF SECTION I:

1. Each lung chamber is (a) *airtight.*
2. The outer boundaries of the thoracic cavity are the (a) *diaphragm,* (c) *chest wall,* and (e) *superior mediastinum.*
3. The pulmonary and parietal pleurae (b) *form a closed sac.*
4. Normally, each lung is extended to fill (a) *all* of the available space.
5. The greater the concentration of molecules in a given space, the (a) *greater* the pressure within the space.
6. Molecules create pressure by (b) *colliding with a surface.*
7. The pleural space is (a) *a potential cavity.*
8. A (c) *pulling* force maintains the lungs in an extended position.
9. Each lung occupies its own (b) *closed* cavity.
10. Increasing the capacity of a container (c) *lowers* the pressure within that container.
11. During inspiration, intrapulmonary pressure (a) *falls.*
12. During inspiration, intrapleural pressure (a) *falls.*
13. Negative pressure has a (b) *sucking* effect.
14. Positive pressure refers to pressure which is (c) *greater than atmospheric.*
15. During inspiration, (b) *inequality of pressure* causes air to move into the lungs.

Turn to page 77.

16. During expiration, (b) *inequality of pressure* causes air to move out of the lungs.

17. Within a space, molecules distribute themselves (c) *evenly.*

18. Negative pressure refers to pressure which is (b) *less than atmospheric.*

19. During expiration, intrapleural and intrapulmonary pressures (b) *rise.*

20. During normal respiration, pressure within the pleural space is always (b) *negative.*

21. Air (or molecules) moves from an area of (a) *greater to lesser* pressure.

22. The lungs probably are held in an extended position by (b) *negative pressure within the pleural space.*

23. The lungs probably are held in expansion by (b) *cohesion of the pulmonary and parietal pleurae.*

If you missed more than five questions, we suggest that you study (or review) Section I before going on. (Section I starts on page 1.)

To begin Section II, turn to page 78.

Section II

RATIONALE OF THERAPY

In section I of this course, we noted that normal respiration depends on several factors, one of them being the characteristic movement of air (molecules) from an area of greater pressure to one of lesser pressure.

Other important factors which we described are the negative pressure and cohesion within the pleural space; these conditions appear to hold the lungs in apposition to the chest wall, diaphragm, and mediastinal area. They prevent the lungs from recoiling to their "unstretched" size, and thus they foster the pressure changes which occur in normal respiration.

Now it's time to consider what happens when these essential conditions are disrupted in our patient, Mr. Marlin.

Mr. Marlin's history and diagnostic tests reveal the presence of a pathological condition in his left lung. Surgery is indicated, and today is the day. In fact, Mr. Marlin is in the operating room now; and Dr. Stone is ready to begin the operation. Dr. Stone incises the chest muscles, removes a portion of a rib, and penetrates the left parietal pleura, thereby opening the pleural cavity to the air and inducing a pneumothorax on that side.

Complete the following sentence by choosing the correct alternative. (Turn to the page indicated beside your choice.)

Pneumothorax is the presence of:

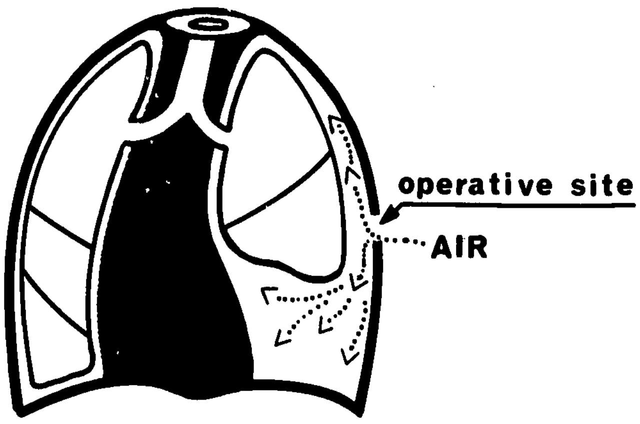
A pathological condition within the lung.	page 87
Cohesion and negative intrapleural pressure.	page 89
Atmospheric pressure within the pleural space.	page 91

YOUR ANSWER: Mr. Marlin's left lung would cease to function when it collapses because normal respiration occurs only when atmospheric and intrapulmonary pressures are unequal.

Right! When the lung has collapsed intrapulmonary and atmospheric pressures equalize, and the characteristic movement of air from an area of greater pressure to one of lesser pressure ceases.

In Mr. Marlin's case, pneumothorax and the resultant collapse of the lung are due to surgical opening of the thoracic cavity (see the diagram).

Accidental chest wounds (from a bullet, knife, auto accident, etc.) also cause pneumothorax. Still another cause is leakage of air from the alveoli of the lung. Sometimes, for example, a person who is susceptible may experience a spontaneous pneumothorax — the pulmonary pleura may tear because of vigorous coughing or sneezing. Or air may leak into the pleural space because of a disease process which involves the pulmonary pleura.



Which of the following causes pneumothorax?

Coughing and sneezing.	page 90
Air in the alveoli of the lung.	page 93
Traumatic puncture of the pleura.	page 96

(from page 91)

YOUR ANSWER: The diagram shows that Mr. Marlin's left lung occupies its normal position.

No, not exactly.

You're right that the position of the lung is normal in that it is still attached to the tracheobronchial tree and is located on the left side of the chest.

Normally, however, the lung fills its chamber at all times. It is thought to be held in a "stretched" position (in apposition to the chest wall, diaphragm, and mediastinal area) by the suctioning effect of negative intrapleural pressure together with cohesion of the moist pleural surfaces. When these conditions are disrupted (as when the surgeon penetrates the parietal pleura), intrapleural pressure becomes atmospheric and the lung assumes its "unstretched" shape.

Please RETURN to page 91 and select the correct alternative.

YOUR ANSWER: Mr. Marlin's left lung would cease to function when it collapses because normal respiration occurs only when atmospheric and intrapulmonary pressures are negative.

Wrong.

Remember that "atmospheric" pressure refers to the pressure in the atmosphere. A pressure greater than atmospheric is "positive" pressure. "Negative" pressure is a pressure which is *less* than that of the atmosphere.

Normal respiration occurs partly because of the characteristic movement of air from an area of greater pressure to an area of lesser pressure. (You'll recall that we discussed this in Section I.) When intrapulmonary pressure is less than atmospheric, air moves into the lungs. Then, when intrapulmonary pressure becomes greater than atmospheric, air moves out of the lungs. When a lung has collapsed, intrapulmonary and atmospheric pressures become equal, thus making normal respiration impossible.

Please RETURN to page 85 and choose the correct answer.

YOUR ANSWER: The diagram shows that Mr. Marlin's left lung has been partially resected.

No.

The reason that the left lung appears to be much smaller than the right is that the left lung has assumed its "unstretched" shape.

Remember that normally the lung is held in an expanded position (so that it fills its entire chamber). Factors which appear to contribute to this continuous expansion are the sucking effect of negative intrapleural pressure and cohesion of the moist pleural surfaces.

When these conditions are disrupted (as when the surgeon penetrates the parietal pleura), intrapleural pressure becomes atmospheric; the pleural surfaces separate; and the elastic fibers of the lung are released from "stretch."

Please RETURN to page 91 and select the correct alternative.

YOUR ANSWER: Postoperative leakage of air into the pleural space causes intrapleural pressure to rise in tension pneumothorax.

Partly right.

Although you're right that postoperative leakage of air into the pleural space is part of it, this alone would not cause tension pneumothorax. The other important factor is that this intrapleural air has no escape route. As we said, this situation sometimes occurs with closed chest drainage. We'll explain it in more detail later.

The important thing we wanted you to recall was a principle we discussed in Section I of this course, i.e., increasing the concentration of molecules within a space increases the pressure in that space.

(Note: If you haven't gone through Section I, perhaps you would find it valuable to do so.)

Now please RETURN to page 96 and choose a better answer.

(from page 92)

YOUR ANSWER: Negative intrapleural pressure and cohesion of the pleurae are essential to normal respiration.

That's right.

As we've noted before, it appears that the suctioning effect of negative intrapleural pressure together with cohesion of the moist pulmonary and parietal pleurae are important factors in holding the lung in an expanded state. These conditions must be re-established if Mr. Marlin's operated lung is to function normally.

We said that as Dr. Stone closes the operative site, air and serosanguinous fluid are present within Mr. Marlin's left pleural cavity. To restore the normal situation, the air and drainage fluid must be removed; and Mr. Marlin's pleural cavity must be kept closed to the atmosphere.

What then is the purpose of closed chest drainage? (Fill in the missing words.)

To re-establish normal respiration by removing ————
and ———— from the closed pleural space.

Now turn to page 95.

YOUR ANSWER: The diagram shows that Mr. Marlin's left lung recoiled to its unexpanded size.

You're right.

When the surgeon penetrates the parietal pleura, intrapleural pressure becomes atmospheric; cohesion of the pleural surfaces is disrupted; and the lung assumes its "unstretched" shape.

Collapse of the lung may be partial, or complete. If the lung is completely collapsed, intrapulmonary pressure equalizes with that of the atmosphere. Then, since there is no longer a difference between these pressures, air cannot move into the lung.

In accord with our discussion of pressure in Section I, why would Mr. Marlin's left lung cease to function when it collapses?

(Complete the following sentence with the correct alternative.) Normal respiration occurs only when atmospheric and intrapulmonary pressures are:

Unequal.	page 79
Negative.	page 81
Equal.	page 88

REVIEW OF SECTION II

Before we discuss the apparatus, let's take a moment to review the important ideas in this section. On a piece of paper, write down the words which correctly complete the following sentences:

1. Pneumothorax is caused by the entrance of ——— into the pleural space.
2. When the surgeon opens the pleural space by cutting through the parietal pleura, the lung ———.
3. In tension pneumothorax, intrapleural pressure ——— because of an increased concentration of molecules.
4. Pneumothorax is characterized by ——— pressure within the pleural space.
5. To restore normal respiration following thoracic surgery, ——— intrapleural pressure and ——— of the pleurae must be re-established.
6. The purpose of closed chest drainage is to restore normal respiration by evacuating ——— and ——— from the pleural space.
7. Normal respiration can occur only when pressures in the atmosphere and within the lung are ———.

To check your answers, turn to page 99.

YOUR ANSWER: Pneumothorax is the presence of a pathological condition within the lung.

No.

A pathological condition in the lung can *cause* pneumothorax, however. (We'll discuss causes of pneumothorax soon.)

Perhaps you are beginning the course with Section II and therefore may not have enough background information to choose the correct answer. Let's go over some points we discussed in Section I: Normally, negative intrapleural pressure and cohesion appear to work together to hold the lungs in apposition to the chest wall, diaphragm, and mediastinal area. Negative pressure itself has a sucking effect; and this effect is augmented by cohesion of the moist pulmonary and parietal pleurae.

As long as these two conditions are present, lung tissue remains "stretched," and the lungs grow larger and smaller as the respiratory muscles contract and relax.

When the surgeon penetrates the parietal pleura, he disrupts these two conditions and opens the pleural space so that it is in contact with the atmosphere. Since air moves from an area of greater pressure to one of lesser pressure, it moves into the opened pleural space.

Please RETURN to page 78 and choose the correct answer.

(from page 85)

YOUR ANSWER: Mr. Marlin's left lung would cease to function when it collapses because normal respiration occurs only when atmospheric and intrapulmonary pressures are equal.

No.

When these pressures are equalized, normal respiration is impossible.

In Section I of this course, we pointed out that air (molecules) characteristically moves from an area of greater pressure to an area of lesser pressure. This characteristic is one of the factors that makes normal respiration possible.

Here again is what happens: On inspiration, intrapulmonary pressure falls below atmospheric pressure—air moves into the lung. On expiration, intrapulmonary pressure rises above atmospheric pressure—air moves out of the lung.

When a lung has collapsed, intrapulmonary pressure changes no longer occur.

Please RETURN to page 85 and select the correct answer.

YOUR ANSWER: Pneumothorax is the presence of cohesion and negative intrapleural pressure.

Wrong.

It represents the disruption of cohesion and of negative intrapleural pressure. Remember that pressure within the pleural space is always negative in the normal situation. The suctioning effect of negative intrapleural pressure plus cohesion of the moist pulmonary and parietal pleurae appear to work together to hold the lungs in apposition to the chest wall, diaphragm, and mediastinal area.

When the surgeon penetrates the parietal pleura, he opens the pleural space so that it is in contact with the atmosphere. Since air moves from an area of greater pressure to one of lesser pressure, it moves into the opened pleural space, thus disrupting the effects of negative intrapleural pressure and cohesion.

Please RETURN to page 78 and choose the correct answer.

YOUR ANSWER: Coughing and sneezing cause pneumothorax.

Not ordinarily.

This *can* happen, but only in a person who is susceptible. If, for example, there are areas on the pulmonary pleura which are "weak," vigorous coughing or sneezing might cause such an area to tear, in which case the person would have a spontaneous pneumothorax. Such occurrences are relatively infrequent, however.

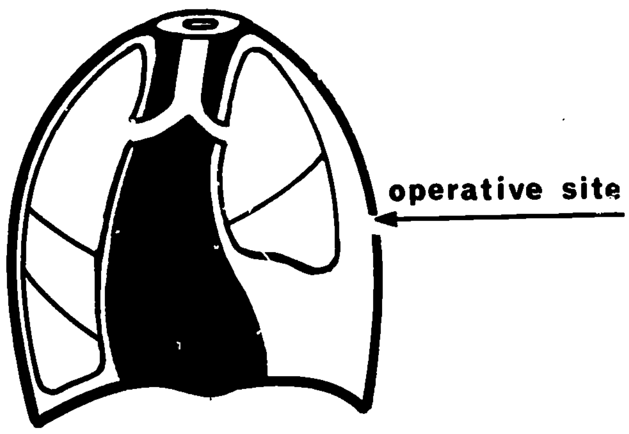
One of the more common causes of pneumothorax is accidental trauma. Whenever a bullet, knife, or broken rib perforates the parietal (or pulmonary) pleura, a pneumothorax results.

Please RETURN to page 79 and choose a better answer.

YOUR ANSWER: Pneumothorax is the presence of atmospheric pressure within the pleural space.

Correct. When Dr. Stone penetrates Mr. Marlin's parietal pleura, he opens the pleural space so that it is in contact with the atmosphere; atmospheric pressure moves into the lesser pressure area within the pleural space.

Here's what can happen to Mr. Marlin's lung when the suctioning effect of negative intrapleural pressure together with cohesion is disrupted: (See the diagram.)



As you will note, the lung no longer fills its chambers. We mentioned earlier that lung tissue is composed of elastic fibers which might be compared to rubber bands.

With this in mind, decide which of the alternatives below correctly completes the following statement. The above diagram shows that Mr. Marlin's left lung:

Occupies its normal position.	page 80
Has been partially resected.	page 82
Recoiled to its unexpanded size.	page 85

YOUR ANSWER: An increased concentration of molecules in a closed space causes intrapleural pressure to rise in tension pneumothorax.

Good. You remembered that the greater the concentration of molecules in a space, the greater the pressure in that space. In tension pneumothorax, an increasing amount of air is trapped within a closed space. Since tension pneumothorax is of special concern in relation to closed chest drainage, we'll discuss it again later in the course.

To get back to the operating room: Dr. Stone has removed a portion of Mr. Marlin's left lung and is preparing to close the operative site. The anesthetist is expanding the operated lung mechanically. And as he pushes the lung out against the rib cage, Dr. Stone closes the chest. Pressure within the pleural space is still atmospheric and, because of the operation, serosanguinous fluid will collect within this cavity.

The job now is to restore normal function to Mr. Marlin's left lung. We know that normal respiration depends on a number of anatomical and physiological relationships (we discussed some of these previously). If Mr. Marlin's lung is to function normally again, these relationships must be re-established.

Based on our earlier discussion, which of the following is essential to normal respiration?

Negative intrapleural pressure and cohesion of the pleurae.	page 84
Distension of the lung by negative intrapulmonary pressure.	page 94
Atmospheric pressure within the pleural cavity.	page 97

YOUR ANSWER: Air in the alveoli of the lung causes pneumothorax.

Not exactly.

It's not the air that's *in* the alveoli of the lung, but rather the air that leaks *out* of the alveoli. Since the alveoli are the "air sacs" of the lung, they normally contain air.

In certain instances, air may leak from the lung into the pleural space. This can happen when the pulmonary pleura tears spontaneously or is involved in a disease process.

One of the more common causes of pneumothorax is accidental trauma. Whenever a bullet, knife, or broken rib perforates the parietal (or pulmonary) pleura, a pneumothorax results.

Please RETURN to page 79 and choose a better answer.

(from page 92)

YOUR ANSWER: Distension of the lung by negative intrapulmonary pressure is essential to normal respiration.

No, you have the wrong idea.

Normal respiration depends on several important factors, and we have discussed only a few of these.

In Section I of this course (which you may not have read), we emphasized that the elastic lung is held in distension because of the continuous apposition of the pulmonary and parietal pleurae. And it appears that the suctioning effect of negative intrapleural pressure together with cohesion of the moist pleural surfaces play an important role in maintaining this apposition.

These conditions must be re-established if Mr. Marlin's operated lung is to function normally. With that in mind, please RETURN to page 92 and choose the correct answer.

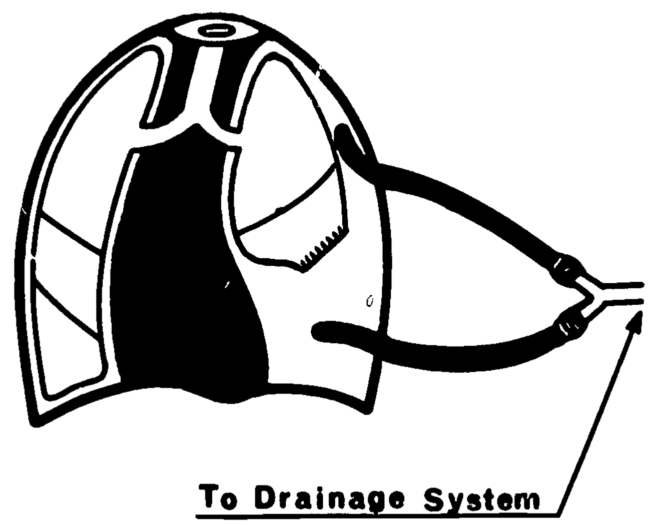
The purpose of sealed chest drainage is to re-establish normal respiration by removing *air* and *fluid* (*drainage*) from the closed pleural space.

That's right.

Air and fluid must be removed so that Mr. Marlin's lung can once again occupy the entire cavity.

To facilitate removal of the intrapleural air and fluid, Dr. Stone does the following: As he closes the chest cavity, he inserts at least one chest catheter (thoracotomy tube) so that its tip is located just inside the chest wall (in the pleural space); he sutures the catheter tightly in place.

Frequently *two* catheters are inserted in the pleural space, in which case one is placed near the apex (to remove air) while the other is placed in the lower part of the chest (to remove fluid). See the diagram.



In Mr. Marlin's case, Dr. Stone has used two catheters, and they are now in place. So we're almost ready to talk about the various kinds of drainage apparatus which might be connected to them.

Please turn to page 86.

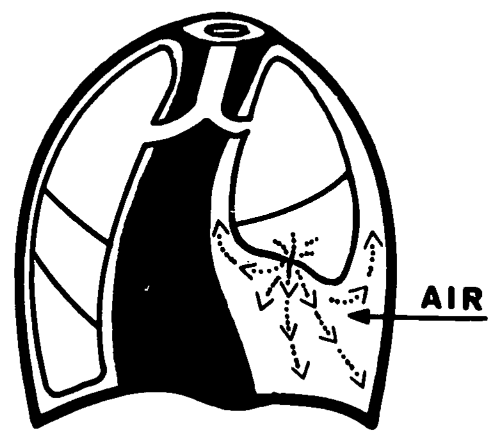
(from page 79)

YOUR ANSWER: Traumatic puncture of the pleura causes pneumothorax.

Correct. The trauma may be surgical or accidental (bullet, knife, broken rib). Leakage of air from the lung through a tear or disease process in the pulmonary pleura also can cause pneumothorax.

Now let's consider *tension pneumothorax:* This condition can develop when air leaks into the pleural space and has no way to escape from it. As more and more air accumulates in the pleural space, pressure within that space rises.

Intrapleural pressure may build to the point that it causes "mediastinal shift." In other words, this pressure may push the heart and other structures in the mediastinal area toward the unaffected lung (see diagram). If the pressure becomes great enough, it can collapse the unaffected lung and cause other severe damage.



Tension pneumothorax is of particular interest to us, since it sometimes results from postoperative leakage of air *together* with improper functioning (or handling) of the closed drainage apparatus. (We'll go into this in detail later.)

In accord with our discussion in Section I, what causes intrapleural pressure to rise in tension pneumothorax?

Postoperative leakage of air into the pleural space.	page 83
An increased concentration of molecules in a closed space.	page 92
Shift of the mediastinal structures toward the unaffected lung.	page 98

YOUR ANSWER: Atmospheric pressure within the pleural cavity is essential to normal respiration.

Wrong.

One of the postoperative problems is that the pressure within the pleural space *is* atmospheric. Remember that air moves into the pleural cavity when the chest is opened. To restore normal respiration, intrapleural pressure must be reduced.

In Section I of this course (which you may not have read), we emphasized that the elastic lung normally is held in apposition to the chest wall, diaphragm, and mediastinal area. It appears that the suctioning effect of negative intrapleural pressure together with cohesion of the moist pleural surfaces play an important role in maintaining this apposition.

These conditions must be re-established if Mr. Marlin's operated lung is to function normally. With that in mind, please RETURN to page 92 and choose the correct answer.

(from page 96)

YOUR ANSWER: Shift of the mediastinal structures toward the unaffected lung causes intrapleural pressure to rise in tension pneumothorax.

No.

Mediastinal shift is a *result* of the increased intrapleural pressure. Shift of the mediastinal structures can even cause collapse of the unaffected lung.

The point is this: If air continues to leak into the affected pleural space and is trapped there, the number of molecules within that space becomes greater and greater. If you'll recall, we said in Section I that the greater the concentration of molecules within a space, the greater the pressure within that space.

(Note: If you haven't gone through Section I, perhaps you would find it valuable to do so.)

Now please RETURN to page 96 and choose a better answer.

Here are the correct answers to our REVIEW OF SECTION II:

1. Pneumothorax is caused by the entrance of *air* into the pleural space.

2. When the surgeon opens the pleural space by cutting through the parietal pleura, the lung *recoils*.

3. In tension pneumothorax, intrapleural pressure *rises* because of an increased concentration of molecules.

4. Pneumothorax is characterized by *atmospheric* pressure within the pleural space.

5. To restore normal respiration following thoracic surgery, *negative* intrapleural pressure and *cohesion* of the pleurae must be re-established.

6. The purpose of closed chest drainage is to restore normal respiration by evacuating *air* and *fluid* from the pleural space.

7. Normal respiration can occur only when pressures in the atmosphere and within the lung are *unequal*.

To begin Section III, please turn to page 100.

Section III

THE APPARATUS

In this section, we'll talk about the water-seal and mechanical suction equipment used in closed drainage of the chest. We'll describe its appearance, how it functions, and related nursing care. In progressing from the simplest type of apparatus to the more complex, we will continue to apply the ideas we've discussed previously in the course.

Let's imagine now that Dr. Stone has closed Mr. Marlin's incision and the two catheters which will remove air and fluid from the pleural space are in place.

Generally, the drainage apparatus which will be used is attached to the patient before he leaves the operating room. Flexible drainage tubing joins the apparatus to the catheters.

When there are two catheters, the two drainage tubes may either be joined to each other at a Y junction, so that they may be attached to one drainage set—or they may be attached to two separate drainage sets.

In Mr. Marlin's case, Dr. Stone has decided that one drainage apparatus will be sufficient. Therefore the flexible tubes coming from Mr. Marlin's two catheters are joined to a Y-shaped glass adapter.

Please go on to page 101.

(from page 100)

Before we talk about specific drainage apparatus, we'll take a little timc to consider some ideas which are applicable no matter what type of equipment is used.

We've stated that the purpose of closed drainage of the chest is to restore normal respiration by removing air and fluid from the closed pleural space. Now let's think about some conditions which affect evacuation of this air and fluid.

One of these conditions is the location of the equipment. It must always be located at a level lower than the patient's chest. It may be placed on the floor beside the patient's bed, but this is hazardous because of the possibility of breakage. The preferred location for the apparatus is in a special rack which is fastened to the bed.

We'll assume that Mr. Marlin has been placed in a recovery room and that responsibility for his postoperative care has been assigned to Miss Wilson, the nurse on duty there. In the operating room, Mr. Marlin's tubing was attached to a drainage apparatus; the tubing was clamped; and the apparatus was placed on top of the bed for the trip to the recovery room.

Obviously, the drainage equipment has to be removed from the top of Mr. Marlin's bed. Suppose that Miss Wilson has to decide what to do with it. Where should she place it? On:

The bedside stand.	page 104
The floor beside his bed.	page 106
A rack attached to the bed.	page 108

YOUR ANSWER: Miss Wilson should "milk" the drainage tubing at regular intervals to prevent stasis of the drainage fluid.

Yes, that's right. Not only should Miss Wilson check to make certain that fluid is flowing through the tubing, but also she should *prevent* clogging by debris which may be building up within the tube.

Another important point about the drainage tubing is that it must be airtight.

Remember that the purpose of therapy is to restore normal respiration and that this goal can be accomplished only by re-establishing normal negative intrapleural pressure and apposition with cohesion of the parietal and pulmonary pleurae.

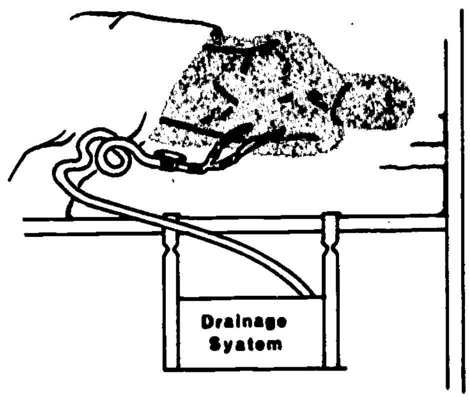
In essence, Mr. Marlin's drainage tubing is an extension of his pleural space. Therefore, any air which leaks into his tubing actually is leaking into his pleural space, thus negating the purpose of therapy and possibly leading to serious complications (we'll discuss the dangers soon).

Why must Mr. Marlin's drainage tubing be airtight? To re-establish:

Extension of the pleural space.	page 113
Negative intrapulmonary pressure.	page 116
Negative intrapleural pressure.	page 119

(from page 112)

YOUR ANSWER: This drawing illustrates a satisfactory arrangement of the tubing:



No, not quite.

In the drawing you chose, extra tubing is coiled beyond the place where the tubing is pinned to the bed.

Look at the drawing again and imagine what would happen if Mr. Marlin turned to lie on his back.

Please RETURN to page 112 and read it again; then select the correct answer.

(from page 101)

YOUR ANSWER: Miss Wilson should place the drainage apparatus on the bedside stand.

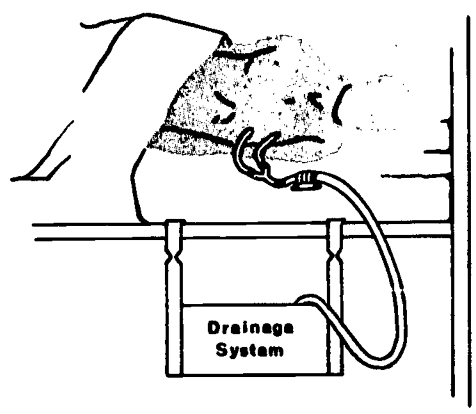
No.

The drainage apparatus must always be located at a level which is lower than the patient's chest. (We'll tell you why later.)

For now, just remember that the best location for the apparatus is in a special rack which is affixed to the patient's bed.

Please RETURN to page 101 and select a better answer.

YOUR ANSWER: This drawing illustrates a satisfactory arrangement of the tubing:



No, indeed.

The tubing should be arranged so that there are no dependent loops. A loop such as the one in the drawing you chose would make drainage more difficult, since the fluid would have to run uphill toward the apparatus.

Also, this drawing shows no allowance for Mr. Marlin's movement in bed. Imagine what would happen if he turned to lie on his back.

Please RETURN to page 112 and read it again; then select the correct answer.

(from page 101)

YOUR ANSWER: Miss Wilson should place the drainage apparatus on the floor beside Mr. Marlin's bed.

You have the right idea. And in some cases, the apparatus *is* placed on the floor beside the bed.

The idea, which apparently you understood, is that the drainage apparatus must always be located at a level which is lower than the patient's chest.

The floor is not the ideal place for this equipment, however. If it's on the floor, there's great danger that it might be kicked over and broken.

Since you had the right idea, please proceed to page 108.

YOUR ANSWER: Miss Wilson should check Mr. Marlin's tubing regularly to observe the nature of the drainage fluid.

Not exactly.

It's true that when she observes the flow of the drainage fluid by looking into the glass adapter in the tubing, she may notice the passage of blood clots. If she does see clots, she should make certain that they are not clogging the tubing (we'll explain what to do about this soon).

The point is that the purpose of checking the tubing is to make sure that the serosanguinous fluid and intrapleural air can pass through it.

Please RETURN to page 110 and select a better answer.

(from page 101)

YOUR ANSWER: Miss Wilson should place the drainage apparatus on a rack attached to the bed.

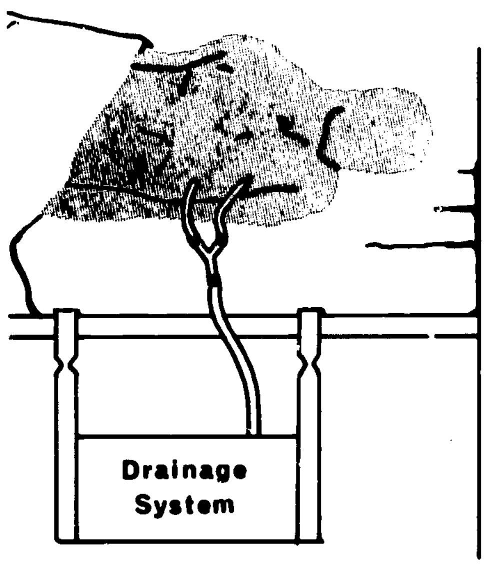
Yes, that's the best answer.

In some cases, the special rack is on wheels. In other cases, the apparatus is placed on the floor beside the bed, but this may be hazardous because of the possibility of breakage and/or elevation above the patient's chest. (We'll explain these dangers later.) If a special rack for holding this equipment is available, that's the best location for it.

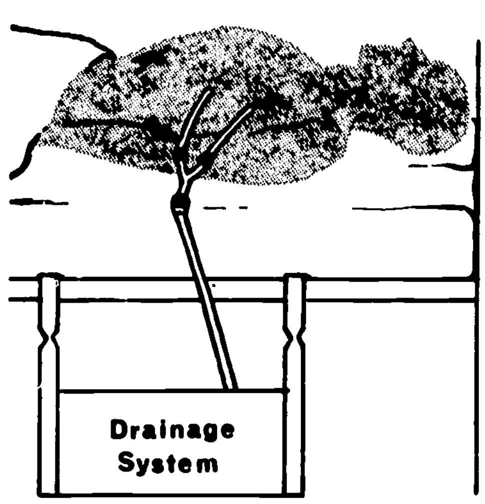
The important thing for the nurse to remember is to make certain that the drainage apparatus is at a level lower than the patient's chest *at all times*.

Another thing which affects drainage is the position of the patient. Although Mr. Marlin should of course be turned (or helped to turn) from his affected side to his back at frequent intervals, lying on (turned toward) his affected side facilitates drainage.

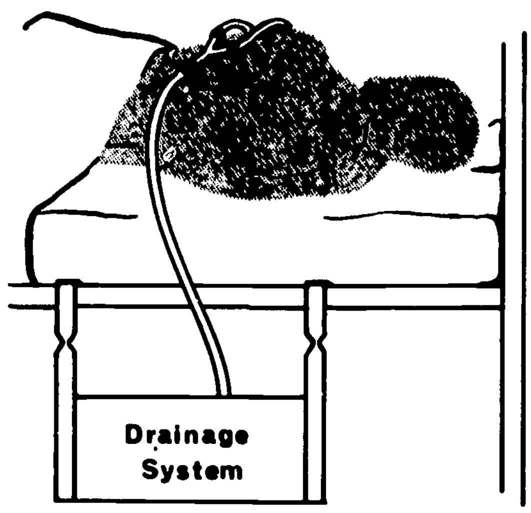
Choose the drawing which shows the best position for drainage:



page 112



page 115



page 117

YOUR ANSWER: Miss Wilson should "milk" the drainage tubing at regular intervals to make certain it is blocked.

Wrong.

The purpose of routinely "milking" the drainage tubing is to help assure that this tubing will be *patent* or unobstructed.

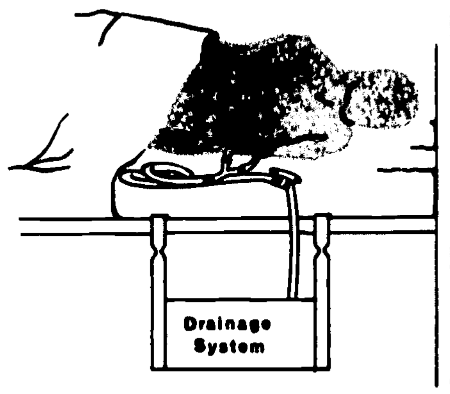
Gentle stroking of the tubing at regular intervals will help to assure that debris such as clotted blood does not collect within the tubing and eventually stop the flow of drainage.

In addition to this preventive "milking," Miss Wilson should check on the movement of fluid through the tubing by observing its flow through the glass adapter and its collection in the drainage apparatus.

Please RETURN to page 114 and select a better answer.

(from page 112)

YOUR ANSWER: This drawing illustrates a satisfactory arrangement of the tubing:



You're right. There's "just enough" tubing, and it's pinned to the bedding so that it falls in a direct line to the apparatus.

Now here's another thing about the tubing: One of the most important things Miss Wilson should do is to make regular checks on the patency of Mr. Marlin's drainage tubing. The tubing *must* be patent if serosanguinous fluid and air are to be evacuated from the pleural space.

Mr. Marlin might accidentally compress the tubing by lying on it or by resting his arm or hand on it. Miss Wilson should be watching for this, and she should look for kinks in the tubing.

Sometimes the tubing will become completely (or partially) clogged by blood clots. In all cases, it should contain a glass adapter so that physicians and nurses can observe the flow of drainage fluid. As we noted earlier, Mr. Marlin's two drainage tubes are joined to each other with a Y-shaped glass adapter inserted at the junction.

Why should Miss Wilson check Mr. Marlin's tubing regularly?

To observe the nature of the drainage fluid.	page 107
To assure that the tubing is patent at all times.	page 114
To make certain the tubing is compressed.	page 120

YOUR ANSWER: Miss Wilson should "milk" the drainage tubing at regular intervals to eliminate kinks in the tubing.

No.

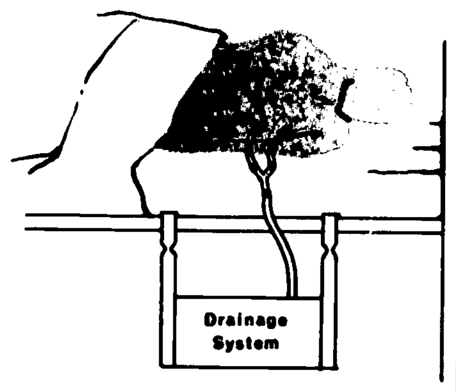
It's true that she should check on the tubing regularly to make certain it has not become kinked and thereby shut off the flow of drainage.

The point we're making here, however, is that not only should Miss Wilson make regular checks on the patency of the tubing, but also she should take an active part in preventing clogging.

Please RETURN to page 114 and select a better answer.

(from page 108)

YOUR ANSWER: This drawing shows the best position for drainage:



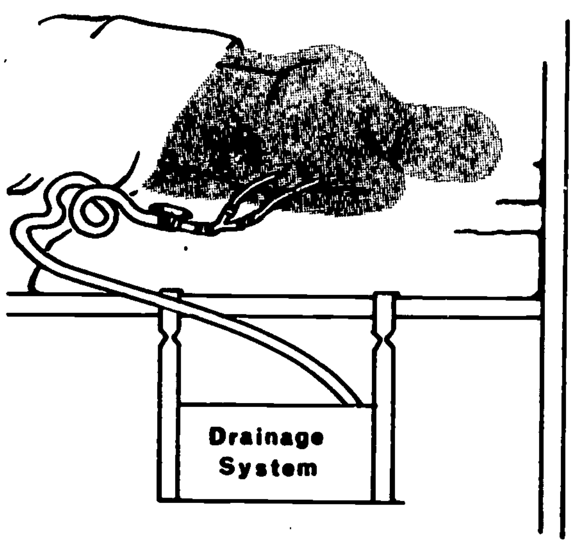
That's right. Although Miss Wilson should help Mr. Marlin turn from his operated (left) side to his back frequently, the best position for drainage is lying turned toward his affected side.

Other conditions which facilitate drainage are having "just enough" drainage tubing and arranging it so that it falls in a direct line (without dependent loops) to the drainage apparatus.

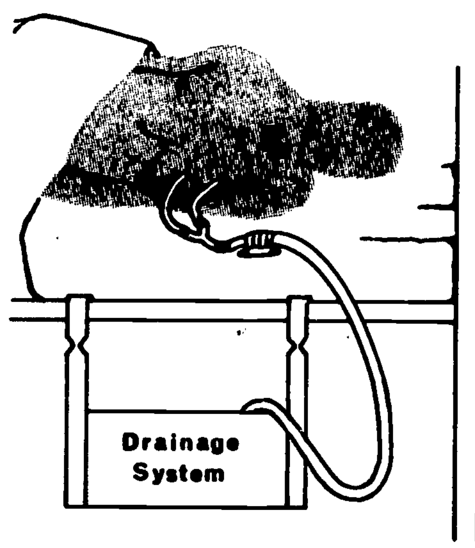
By "just enough" tubing, we mean enough to allow Mr. Marlin to turn easily (without pulling on chest catheters)—but not so much tubing that he becomes tangled in it.

Miss Wilson should assure that the tubing will fall in a direct line to the apparatus by placing either a strip of adhesive tape or a rubber band loosely around the tubing and then pinning it to Mr. Marlin's bedding.

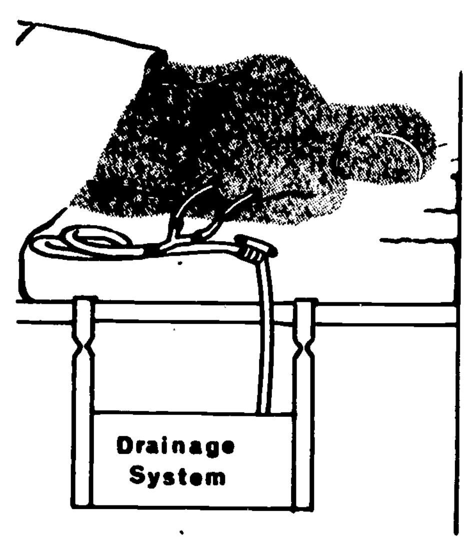
Which of the following illustrates a satisfactory arrangement of the tubing?



page 103



page 105



page 110

(from page 102)

YOUR ANSWER: Mr. Marlin's drainage tubing must be airtight to re-establish extension of the pleural space.

No.

What we said was that Mr. Marlin's drainage tubing actually represents an extension of his pleural space and that, therefore, air leaking into the tubing is leaking into the pleural space.

A primary goal of therapy is to eliminate the pleural space which is present postoperatively. Remember that in normal respiration there is no actual space between these pleurae. In order to restore normal function of Mr. Marlin's operated lung, apposition and cohesion of the parietal and pulmonary pleurae, together with negative intrapleural pressure, must be re-established. If air leaks into the pleural space through the tubing, it will be impossible to accomplish this objective.

Please RETURN to page 102 and select the correct answer.

YOUR ANSWER: Miss Wilson should check Mr. Marlin's tubing regularly to assure that it is patent at all times.

Correct.

In order for serosanguinous fluid and intrapleural air to pass through the tubing, it *must* be patent; Miss Wilson should check regularly to make sure it is neither compressed nor clogged. (Another way to check is to observe the fluid collecting in the drainage apparatus.)

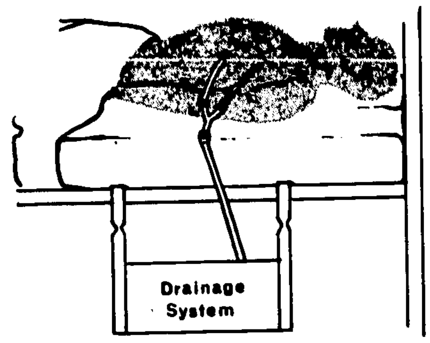
There is something else Miss Wilson can and should do to assure the patency of Mr. Marlin's drainage tubing. About once an hour (or more often), she should "milk" the drainage tubing. By this, we mean that she should gently stroke the tubing in the direction of the drainage apparatus. This will help to assure that any clots which are caught in the tubing will be dislodged and pass out of it.

Why should Miss Wilson "milk" the drainage tubing at regular intervals?

To prevent stasis of the drainage fluid.	page 102
To make certain the tubing is blocked.	page 109
To eliminate kinks in the tubing.	page 111

(from page 108)

YOUR ANSWER: This drawing shows the best position for drainage:



No, it's not the best.

It's true that Mr. Marlin will have to lie on his back part of the time; but he should spend a greater amount of time turned toward his affected side, since this facilitates drainage. Miss Wilson, of course, should make certain that he does turn from his affected side to his back frequently.

Please RETURN to page 108 and choose another drawing.

YOUR ANSWER: Mr. Marlin's drainage tubing must be airtight to re-establish negative intrapulmonary pressure.

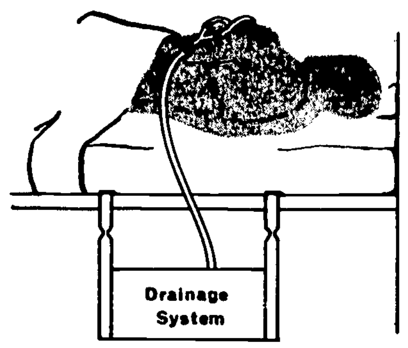
Not quite.

Re-establishment of negative *intrapleural* pressure is our goal.

Remember that when his thoracic cavity was open to the air, Mr. Marlin's intrapleural pressure was positive. Normal respiration depends on apposition with cohesion of the parietal and pulmonary pleurae together with negative intrapleural pressure. These conditions must be re-established if normal respiration is to be restored. If air leaks into the pleural space through the tubing, it will be impossible to accomplish this objective.

Please RETURN to page 102 and select the correct answer.

YOUR ANSWER: This drawing shows the best position for drainage:



Wrong.

We've just stated that lying turned toward the affected side facilitates drainage.

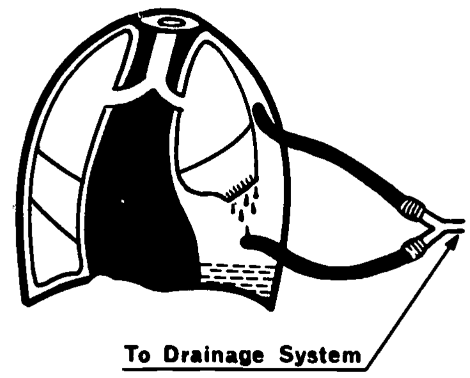
If Mr. Marlin lay on his right side (as in the drawing you chose), drainage fluid would have to run uphill, rather than simply down and out through the tubing.

Although Miss Wilson should make certain that Mr. Marlin turns from his affected side to his back frequently, spending a greater amount of time turned toward his operated (left) side will facilitate drainage.

Please RETURN to page 108 and choose another drawing.

(from page 126)

YOUR ANSWER: This diagram illustrates consequences of occluded drainage tubing:



Not exactly.

Although this diagram shows serosanguinous fluid dripping from the raw surface of the lung, only a relatively small quantity of fluid is present within the pleural space. It is "usual" to have some fluid in the pleural space following pulmonary surgery, as in Mr. Marlin's case.

We're thinking about the serious consequences which can develop because of compression or clogging of the drainage tubing. If the fluid which drains into the pleural cavity postoperatively cannot escape through the drainage tubing, it simply collects in the pleural space. As the fluid level in the pleural space rises, it compresses the affected lung. Since the lung cannot displace the fluid, normal expansion of that lung is impossible.

Please RETURN to page 126 and choose the correct answer.

YOUR ANSWER: Mr. Marlin's drainage tubing must be airtight to re-establish negative intrapleural pressure.

You are correct.

Since Mr. Marlin's drainage tubing represents an extension of his pleural space, air leaking into the tubing would perpetuate the atmospheric intrapleural pressure present during the operation—thus defeating the purpose of therapy.

Miss Wilson can help to assure that the drainage system will be airtight by taping all connecting points or checking to see that they are securely closed. Whenever she observes Mr. Marlin, she should routinely check to see that his chest catheters are securely in place and that the drainage tubing is tightly attached to the glass adapter and to the point where it is connected to the drainage apparatus.

What can Miss Wilson do to prevent air from leaking into Mr. Marlin's drainage tubing? (Choose the most complete answer.)

Look at the junction containing the Y-shaped glass adapter.	page 122
Tape the places where the tubing is connected.	page 125
Check the insertion of the chest catheters.	page 129

YOUR ANSWER: Miss Wilson should check Mr. Marlin's tubing regularly to make certain it is compressed.

No, you've missed the point.

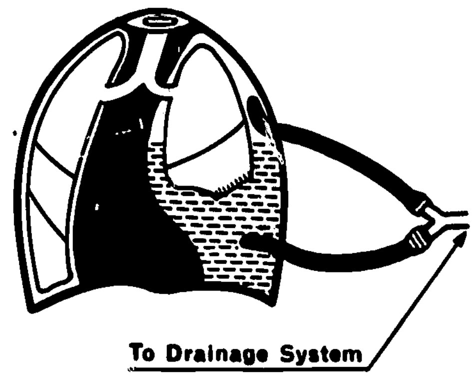
The tubing must *not* be compressed if drainage fluid and air are to be evacuated through it.

Miss Wilson should check regularly to see that Mr. Marlin is not lying on the tubing, or resting his arm on it. Also she should check on the patency of the tubing by observing the flow of fluid through the glass adapter. In order for fluid and air to pass through the tubing, it must be patent.

Please RETURN to page 110 and select a better answer.

(from page 126)

YOUR ANSWER: This diagram illustrates consequences of occluded drainage tubing:



Right. As the fluid accumulates in the pleural space, it can compress Mr. Marlin's lung, making normal expansion impossible. And it can result in a shift of the mediastinal area toward the unoperated side.

Here's something else: Occlusion of the tubing also cuts off the route by which air is evacuated from the pleural cavity. You'll recall that some air generally remains in the cavity following the operation. Additional air may leak into the pleural space after the chest has been closed. The danger of mediastinal shift becomes even greater when leakage of air into the space accompanies occlusion of the tubing.

Earlier in the course, we noted that Miss Wilson should observe Mr. Marlin's drainage tubing to make certain it is airtight. (Since the tubing is an extension of the pleural space, air leaking into the tubing actually is leaking into the pleural space.)

Another way that air may leak into the pleural space is through the opening in the pulmonary pleura. When the surgeon sutures the operated area, he attempts to decrease this possibility. Still, air generally leaks through the sutured area until it has healed.

What increases the possibility of mediastinal shift? (Choose the best answer.)

Trapping of air leaked into the pleural space.	page 130
Suturing the cut surfaces of the operated lung.	page 133
Leaking of air into the drainage system.	page 135

YOUR ANSWER: To prevent air from leaking into Mr. Marlin's drainage tubing, Miss Wilson can look at the junction containing the Y-shaped glass adapter.

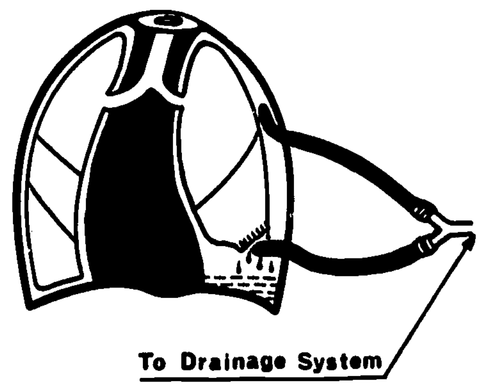
Partly right.

You're right that she should check on the connection between the drainage tubing and the glass adapter. However, she can do more than that to help assure that the tubing is airtight.

We noted that all connecting points should be securely closed. Please RETURN to page 119 and select a more complete answer—the one which includes *all* connecting points.

(from page 126)

YOUR ANSWER: This diagram illustrates consequences of occluded drainage tubing:



Wrong.

The diagram you chose shows an almost-expanded lung with only a small quantity of fluid in the pleural space. From this picture, it appears that the drainage tubing is patent and that fluid and air are being evacuated properly.

Now if the drainage tubing were occluded, fluid draining into the pleural cavity postoperatively would simply collect there. As the fluid level in the pleural space rose, it would compress the affected lung, thus making normal expansion of that lung impossible.

Please RETURN to page 126 and choose the correct answer.

(from page 130)

YOUR ANSWER: Mediastinal shift is a serious matter because it can trap air within the pleural space.

Wrong.

Mediastinal shift can develop because air *is* trapped within the pleural space. Not only is a small amount of air trapped there but, in most cases, air is continually added so that pressure continues to rise.

When intrapleural pressure becomes great enough, mediastinal shift is the result. Displacement and compression of the mediastinal structures, together with collapse of the healthy lung, lead to the demise of the patient within a few minutes.

Please RETURN to page 130 and select the best answer.

YOUR ANSWER: To prevent air from leaking into Mr. Marlin's drainage tubing, Miss Wilson can tape the places where the tubing is connected.

Right; that's the most complete answer. If the connecting points are not already taped, she should tape them to make certain that the tubing will remain airtight.

So far, we've discussed four general rules to guide the nurse in her care of the patient being treated by closed chest drainage. To help you remember them, read these important ideas again:

1. *Keep the drainage apparatus at a level lower than the patient's chest at all times.*

2. *Check the drainage tubing regularly for patency.*

3. *"Milk" the drainage tubing about once an hour to prevent clogging.*

4. *Observe the drainage tubing to make certain it is airtight.*

Please go on to page 126.

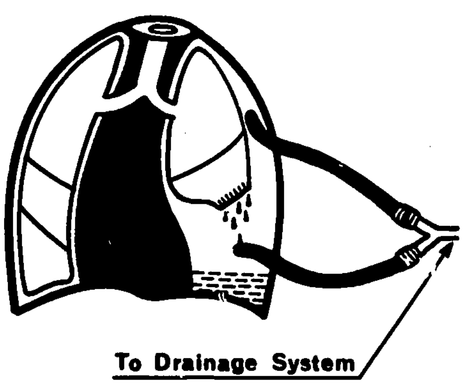
(from page 125)

Now let's see what can happen to Mr. Marlin if his drainage tubing becomes compressed or clogged. One thing that is apparent is that the serosanguinous fluid oozing into the pleural cavity cannot escape through the tubing. Since it must go somewhere, it collects in the pleural space.

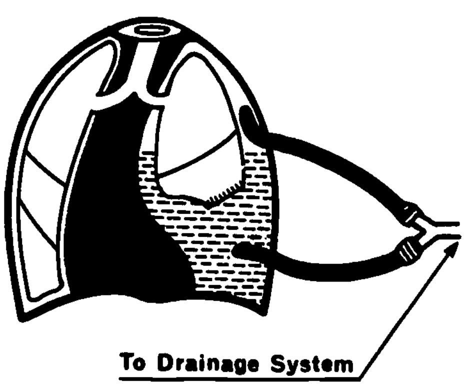
As the fluid accumulates, it occupies more and more space which should be occupied by lung tissue. It can compress Mr. Marlin's operated lung, making expansion impossible. And if fluid continues to accumulate in the pleural space, this can result in a shift of the mediastinal area toward the unoperated side.

Even if mediastinal shift does not occur, other serious complications can develop because of obstructed drainage tubing.

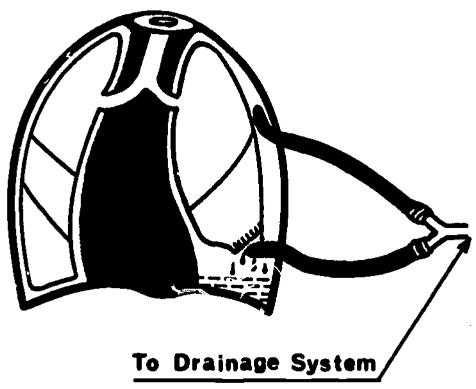
Which of the following diagrams illustrates consequences of occluded drainage tubing?



page 118



page 121



page 123

YOUR ANSWER: If Miss Wilson believes Mr. Marlin has tension pneumothorax, the first thing she should do is check for compressed tubing.

No.

Since this generally is an emergency, she should not delay a moment before notifying a physician.

If the drainage tubing should happen to be compressed, this may be part of the difficulty. But it may be *only* a part! And treatment to relieve the condition probably will have to be administered by a physician.

Remember that if the patient develops mediastinal shift, he can die within a few minutes!

Please RETURN to page 139 and select the best answer.

page 128
(from page 130)

YOUR ANSWER: Mediastinal shift is a serious matter because it can displace the heart and great vessels.

True, but let's take it a step further.

What difference does it make if the heart and great vessels are displaced and compressed? Compression of these vital mediastinal structures, together with collapse of the healthy lung, can lead to the demise of the patient within a few minutes!

Please RETURN to page 130 and choose the best answer.

(from page 119)

YOUR ANSWER: To prevent air from leaking into Mr. Marlin's drainage tubing, Miss Wilson can check the insertion of the chest catheters.

She could do that—and *should* do it.

However, we asked you for the most complete answer. And Miss Wilson can do more than check on the chest catheters, to assure that the tubing is airtight.

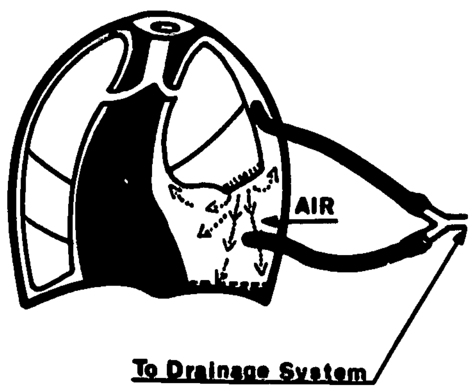
We noted that all connecting points should be securely closed. Please RETURN to page 119 and select a better answer—the one which includes *all* connecting points.

(from page 121)

YOUR ANSWER: Trapping of air leaked into the pleural space increases the possibility of mediastinal shift.

Correct. Air may leak into the pleural space through the drainage tubing or through the cut pulmonary pleura. If this air cannot be evacuated through the drainage tubing, the danger of tension pneumothorax with resultant mediastinal shift is greatly increased. (You'll recall that the greater the concentration of molecules within a given space, the greater the pressure within that space.)

All right. We've said that if this situation persists, the excessive intrapleural pressure will push Mr. Marlin's mediastinal structures toward his unoperated side. And it can collapse his unoperated lung. Here again is a diagram representing the situation we've described:



Remember that the mediastinal area contains vital structures—the heart, great vessels, and trachea. Compression of these structures, together with collapse of the healthy lung, can lead to cardiorespiratory failure within a few minutes.

Why is mediastinal shift a serious matter? Because it can:

Trap air within the pleural space. page 124
Displace the heart and great vessels. page 128
Cause the patient to die in a short time. page 134

YOUR ANSWER: If Miss Wilson believes Mr. Marlin has tension pneumothorax, the first thing she should do is irrigate the chest catheters.

No, the nurse generally would not perform this procedure.

If such irrigation is indicated, it probably will have to be performed by a physician. Since this generally is an emergency, the nurse should notify a physician without delay.

Remember that if the patient develops mediastinal shift, he can die within a few minutes!

Please RETURN to page 139 and select the best answer.

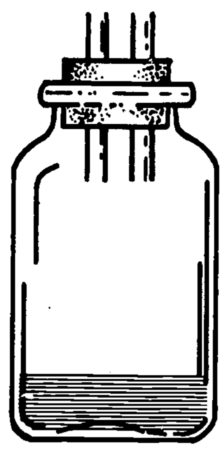
(from page 136)

At the beginning of this section concerning apparatus, we said that Dr. Stone decided one drainage set would be sufficient in Mr. Marlin's case. We'll assume he has chosen to place Mr. Marlin on the simplest kind of closed chest drainage equipment—the one-bottle water-seal apparatus.

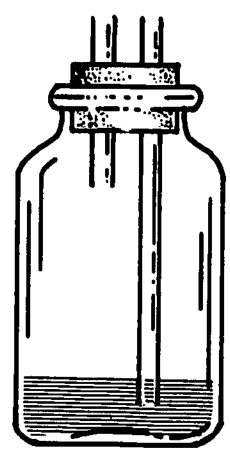
We're going to describe the appearance of this apparatus and explain its various parts; and we'll point out Miss Wilson's responsibilities in relation to it.

Prior to connecting the apparatus to Mr. Marlin's tubing, the first thing we'll notice is that this is a sterile glass bottle which contains about 100 cc. of sterile water. A tight-fitting rubber stopper closes the neck of the bottle and, in fact, is taped in place. The stopper itself contains two hollow tubes, one short and one long. The shorter tube (glass or metal) extends only about one inch into the bottle, while the longer tube (which is glass) terminates under the water, about one-half inch from the bottom of the bottle.

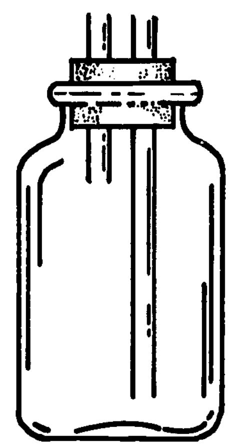
Which of the following represents the one-bottle water-seal apparatus we've described?



page 138



page 141



page 144

YOUR ANSWER: Suturing the cut surfaces of the operated lung increases the possibility of mediastinal shift.

Wrong.

Perhaps we confused you because we're certain you know that suturing of the lung would not increase the possibility of mediastinal shift. In fact, this possibility often is decreased by the manner in which the surgeon sutures the operative site.

The point is this: Even with the most careful suturing technique, there generally is some leakage of air from the opening in the pulmonary pleura into the pleural space. Ordinarily, this "leaked-in" air would be evacuated via the drainage tubing. However, if the tubing is occluded and air is leaking into the pleural space, the "leaked-in" air is trapped there. And *these* are the circumstances which can lead to mediastinal shift.

Please RETURN to page 121 and select the correct answer.

YOUR ANSWER: Mediastinal shift is a serious matter because it can cause the patient to die in a short time.

That's right. Displacement and compression of vital mediastinal structures, together with collapse of the healthy lung, can lead to death within a few minutes.

Since mediastinal shift can be so serious, Miss Wilson should be constantly watchful for signs of its development. First signs may be an increased rate of respiration and the appearance of subcutaneous emphysema, both of which are indications of tension pneumothorax (positive intrapleural pressure).

In subcutaneous emphysema, some of the trapped intrapleural air escapes through the incision in the parietal pleura and moves into the soft tissues, which become "blown up" and feel spongy. Also, the patient may complain of a feeling of pressure within the chest.

As the condition progresses, the patient may develop marked shortness of breath and cyanosis. If palpation of the laryngeal area with the head in the midline discloses deviation of this area toward the unoperated side, this is an indication that mediastinal shift has occurred.

Which of the following would cause Miss Wilson to think Mr. Marlin is likely to have tension pneumothorax with resultant mediastinal shift?

Drainage tubing which is obstructed by blood clots.	page 137
Dyspnea with blueness and puffiness of the skin.	page 139
Deviation of the laryngeal area toward the left side.	page 142

YOUR ANSWER: Leaking of air into the drainage system increases the possibility of mediastinal shift.

Partly right, but not the best answer.

The point is that the danger of mediastinal shift increases where there is no way to evacuate air which is leaking into the pleural cavity. The air may enter through a break or faulty connection in the drainage tubing (remember that the nurse should check the tubing for leaks); or it may leak through the opening in the pulmonary pleura.

No matter where the leaking air comes from, if it is trapped in the pleural space, the danger of mediastinal shift is greatly increased.

Please RETURN to page 121 and select the correct answer.

(from page 139)

YOUR ANSWER: If Miss Wilson believes Mr. Marlin has tension pneumothorax, the first thing she should do is call a physician.

Right. Tension pneumothorax generally is an emergency condition which requires immediate attention by a physician.

Although we've been talking about tension pneumothorax and resultant mediastinal shift mainly in relation to drainage tubing, we want to note here that these conditions can develop because of difficulties with other components of the apparatus as well. We'll discuss these other sources of trouble as we come to them.

Also, we want to mention that some of the other ideas we've covered in relation to drainage tubing apply to the *entire* apparatus. And this too we'll point out to you as we go along.

Now, before we take a look at the rest of the equipment, read these important ideas again:

1. *Keep the drainage apparatus at a level lower than the patient's chest at all times.*
2. *Check the drainage tubing regularly for patency.*
3. *"Milk" the drainage tubing about once an hour to prevent clogging.*
4. *Observe the drainage tubing to make certain it is airtight.*
5. *Watch the patient for signs of tension pneumothorax and mediastinal shift.*
6. *If tension pneumothorax develops, call a physician immediately.*

Try to remember these "guides." Now turn to page 132.

YOUR ANSWER: Drainage tubing which is obstructed by blood clots would cause Miss Wilson to think Mr. Marlin is likely to have tension pneumothorax with resultant mediastinal shift.

Not necessarily.

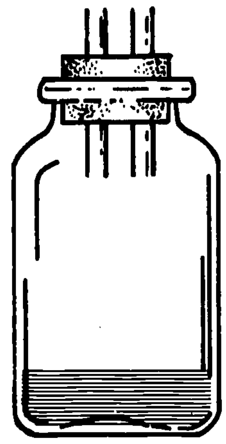
This is, however, a condition which *could* lead to the development of tension pneumothorax and resultant mediastinal shift. If Mr. Marlin's drainage tubing did become obstructed, Miss Wilson should watch him very carefully.

Here again are signs which are likely to appear if Mr. Marlin has tension pneumothorax: increased rate of respiration and subcutaneous emphysema. If intrapleural pressure becomes great enough, his mediastinal area will shift toward the unoperated side, and he will probably develop dyspnea and cyanosis. Deviation of the laryngeal area toward his unoperated side would indicate that this shift has occurred.

Please **RETURN** to page 134 and select the correct answer.

(from page 132)

YOUR ANSWER: This drawing represents the one-bottle water-seal apparatus we've described:



Wrong.

Remember that one tube is much longer than the other. In fact, the longer tube, which is always glass, should extend to about one-half inch from the bottom of the bottle.

Please RETURN to page 132 and read the description again. Then select the correct drawing.

YOUR ANSWER: Dyspnea with blueness and puffiness of the skin would cause Miss Wilson to think Mr. Marlin is likely to have tension pneumothorax with resultant mediastinal shift.

Correct. First signs (an increased rate of respiration and subcutaneous emphysema) are indicative of tension pneumothorax. If mediastinal shift occurs, the patient generally develops dyspnea and cyanosis; and the laryngeal area becomes deviated toward the unoperated side.

If Miss Wilson suspects that Mr. Marlin has tension pneumothorax, she should notify a physician at once. Then, while awaiting his arrival, she should attempt to locate the difficulty which has produced this situation.

If something obvious is wrong with the apparatus (and if it is something she can correct—such as compressed drainage tubing), Miss Wilson should make the necessary adjustment immediately. If it is something more complicated, such as obstructed drainage tubing or catheters, a physician may have to irrigate them (generally this is not a job for the nurse). No matter what the difficulty is, tension pneumothorax generally is an emergency condition which requires immediate attention.

This question should be an easy one. What is the first thing Miss Wilson should do if she believes Mr. Marlin has tension pneumothorax?

Check for compressed tubing.	page 127
Irrigate the chest catheters.	page 131
Call a physician.	page 136

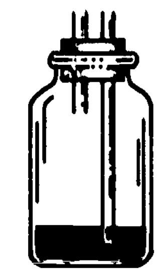
YOUR ANSWER: The drainage apparatus must be located at a level lower than the patient's chest at all times to allow ambulation of the patient.

Not exactly.

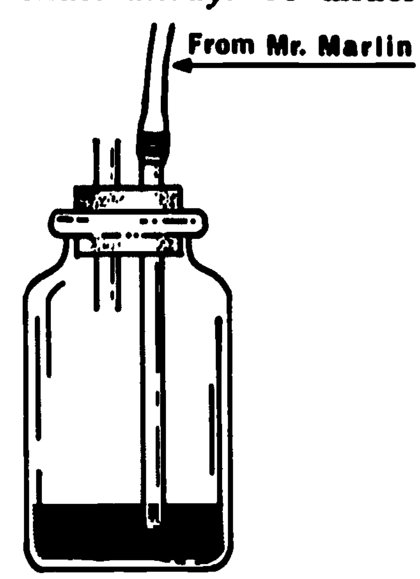
The patient may be ambulated; and if he does walk around, someone should walk with him to carry the drainage apparatus. The reason the drainage apparatus should be carried is to make sure that none of the fluid in it will be siphoned into his chest.

Please RETURN to page 150 and read it again before selecting the correct answer.

YOUR ANSWER: This drawing represents the one-bottle water-seal apparatus we've described:



That's right. You'll note that the longer of the two tubes terminates *under* the water in the bottle. The open lower tip of the longer tube must *always* be under water when the apparatus is attached to Mr. Marlin's drainage tubing (see diagram).



Here's why it's so important to keep the lower end of the longer tube under the water: We already know that in order to restore normal respiration, fluid and air must be evacuated from the pleural space while, at the same time, air is prevented from entering this space. We must have a closed system which allows intrapleural air to exit and prevents outside air from entering.

The water in the water-seal bottle serves this purpose. It acts as a trap door or valve which opens to let intrapleural air out and then closes, sealing the opening and preventing outside air from entering the tubing.

Why should Miss Wilson make certain that the lower tip of the long tube in the water-seal bottle is under water? Because this arrangement prevents:

Drainage of intrapleural fluid.	page 145
Air from leaving the pleural space.	page 147
Air from entering the pleural space.	page 150

(from page 134)

YOUR ANSWER: Deviation of the laryngeal area toward the left side would cause Miss Wilson to think Mr. Marlin is likely to have tension pneumothorax with resultant mediastinal shift.

Not exactly.

You're right that if mediastinal shift has occurred, the laryngeal area will have been moved off-center. In Mr. Marlin's case, however, it would be deviated toward the right side, since that is his unoperated side.

Mediastinal shift generally is accompanied by dyspnea and cyanosis. First signs of trouble, which are those of tension pneumothorax, are an increased rate of respiration and subcutaneous emphysema.

Please RETURN to page 134 and select the correct answer.

YOUR ANSWER: The drainage apparatus must be located at a level lower than the patient's chest at all times to establish negative intrapleural pressure.

Wrong.

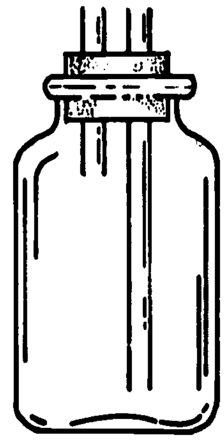
The location of the drainage apparatus has nothing to do with *establishment* of negative intrapleural pressure. As soon as Mr. Marlin breathes after his chest is closed, intrapleural pressure becomes slightly negative.

It is the combination of the sucking effect of negative intrapleural pressure plus fluid in the drainage apparatus which makes elevation of the apparatus above his chest dangerous.

Please RETURN to page 150 and select the right answer.

(from page 132)

YOUR ANSWER: This drawing represents the one-bottle water-seal apparatus we've described:



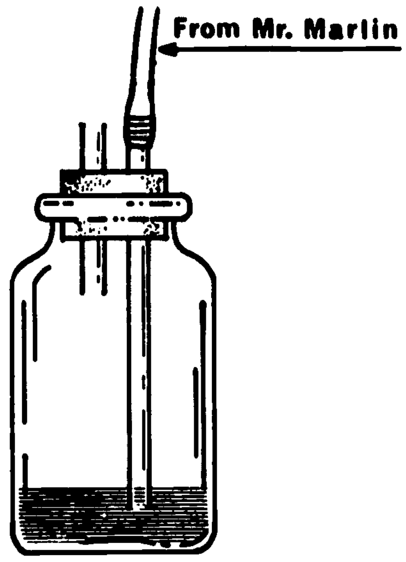
Wrong.

You've forgotten one very important detail. The tubes in the drawing you chose are all right. But remember that something in addition to tubes should be inside the bottle.

Please RETURN to page 132 and read the description again. Then select the correct drawing.

(from page 141)

YOUR ANSWER: Miss Wilson should make certain that the lower tip of the long tube in the water-seal bottle is under water because this arrangement prevents drainage of intrapleural fluid.



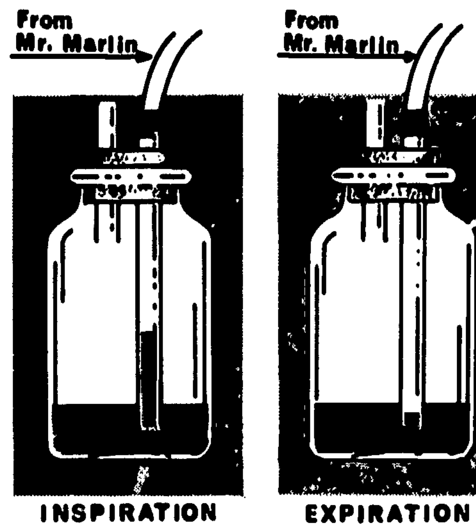
Wrong.

Remember that one of the purposes of using this apparatus is to evacuate fluid and air from the pleural space. Remember also that the drainage tubing is the route of evacuation. If you'll look at the diagram again, you'll see that both fluid and air must exit through the long glass tube inside the bottle.

The term "water-seal" means just what it says. The water in the bottle "seals" the drainage system and prevents outside air from entering the pleural space.

Please RETURN to page 141 and select the correct answer.

YOUR ANSWER: This pair of bottles illustrates proper functioning of Mr. Marlin's drainage apparatus:



Correct.

The rising and falling of Mr. Marlin's intrapleural pressure (during inspiration and expiration) should be reflected in the up-and-down movement of water in the long glass tube. It is important that Miss Wilson observe the water-seal apparatus to make certain the water is fluctuating in this manner.

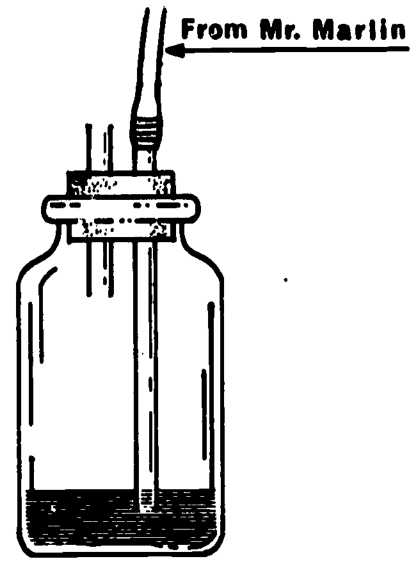
As we said, intrapleural air and drainage are evacuated from Mr. Marlin's pleural space through the long glass tube. This air leaves the bottle through the short tube in the rubber stopper.

If the bottle had no such air vent, intrapleural air would remain in the bottle and pressure within the bottle would rise. Eventually, it could become great enough to prevent evacuation of air from the pleural space (and you'll recall this could lead to tension pneumothorax).

Why must the short tube be open to the atmosphere?

To prevent the escape of air from the pleural space.	page 148
To permit evacuation of intrapleural air from the bottle.	page 154
To prevent atmospheric pressure from entering the bottle.	page 157

YOUR ANSWER: Miss Wilson should make certain that the lower tip of the long tube in the water-seal bottle is under water because this arrangement prevents air from leaving the pleural space.



Wrong.

Remember that one of the purposes of using this apparatus is to evacuate fluid and air from the pleural space. Remember also that the drainage tubing is the route of evacuation. If you'll look at the diagram again, you'll see that both fluid and air must exit through the long glass tube inside the bottle.

The term "water-seal" means just what it says. The water in the bottle prevents outside air from entering the pleural space by sealing the open end of the long glass tube.

Please RETURN to page 141 and select the correct answer.

(from page 146)

YOUR ANSWER: The short tube must be open to the atmosphere to prevent the escape of air from the pleural space.

You didn't mean that, did you?

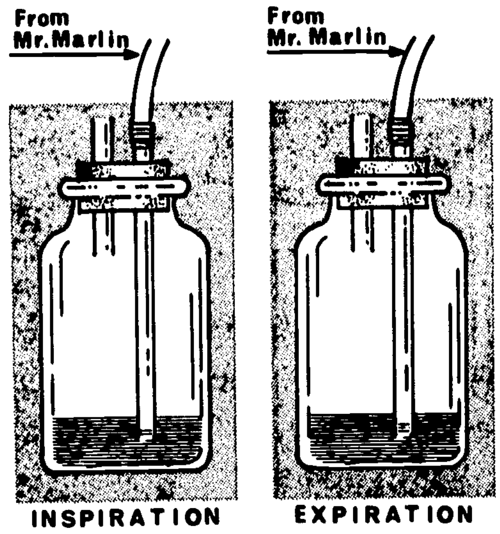
Remember that our goal is to remove fluid and air from Mr. Marlin's operated side.

The point is that if there's no route by which intrapleural air can escape from the bottle, pressure within the bottle will rise. This pressure can become great enough to prevent evacuation of intrapleural air (thus possibly leading to tension pneumothorax).

Please RETURN to page 146 and select the correct answer.

(from page 152)

YOUR ANSWER: This pair of bottles illustrates proper functioning of Mr. Marlin's drainage apparatus:



No.

Remember that there should be an up-and-down movement of the water in the long glass tube and that this movement should be related to respiration.

The lower intrapleural pressure during inspiration should pull or suck water a short distance up the glass tube. During expiration, this water should fall back down into the bottle. The rising and falling of intrapleural pressure (during inspiration and expiration) should be reflected in the rising and falling of water in the long glass tube.

Please RETURN to page 152 and select the drawings which represent this fluctuation of the water.

(from page 141)

YOUR ANSWER: Miss Wilson should make certain that the lower tip of the long tube in the water-seal bottle is under water because this arrangement prevents air from entering the pleural space.

Correct. As soon as Mr. Marlin's chest is closed and he breathes, intrapleural pressure becomes slightly negative. If air entered his pleural space via the tubing, this pressure could become atmospheric again. Water in the water-seal bottle "seals" his pleural space.

To digress a moment, do you remember we emphasized that the drainage apparatus must be kept at a level lower than the patient's chest at all times? Another reason for this location concerns the fact that Mr. Marlin's intrapleural pressure is negative (and has a sucking effect) and that there's fluid in the drainage apparatus.

Suppose the apparatus were elevated above his chest. Fluid in the bottle would simply run or be siphoned back into his chest, wouldn't it? To avoid this, Miss Wilson should be cautious about the location of the apparatus at all times. For example, if Mr. Marlin is being ambulated, Miss Wilson should accompany him or make sure that someone else does. And the apparatus should be carried, being held a few inches from the floor.

Why must the drainage apparatus be located at a level lower than the patient's chest at all times?

To allow ambulation of the patient.	page 140
To establish negative intrapleural pressure.	page 143
To prevent backflow of fluid into the pleural space.	page 152

(from page 154)

YOUR ANSWER: On the marking tape, Miss Wilson should record the quantity of blood being lost.

Partly right.

It's true that Dr. Stone will want to know about the quantity of fluid being collected in the drainage apparatus. He will also want to know how fast it is collecting there.

When Dr. Stone knows the quantity of drainage of serosanguinous fluid in relation to time, he will have a basis for calculating the volume of blood which should be replaced.

Please RETURN to page 154 and select a better answer.

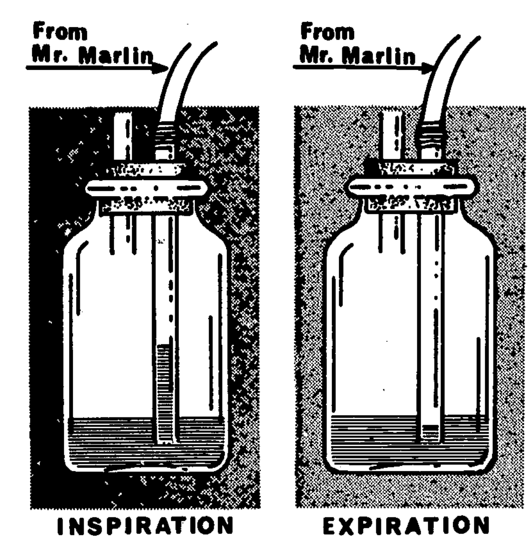
YOUR ANSWER: The drainage apparatus must be located at a level lower than the patient's chest at all times to prevent backflow of fluid into the pleural space.

That's right. Elevating the apparatus would cause fluid to run into his chest.

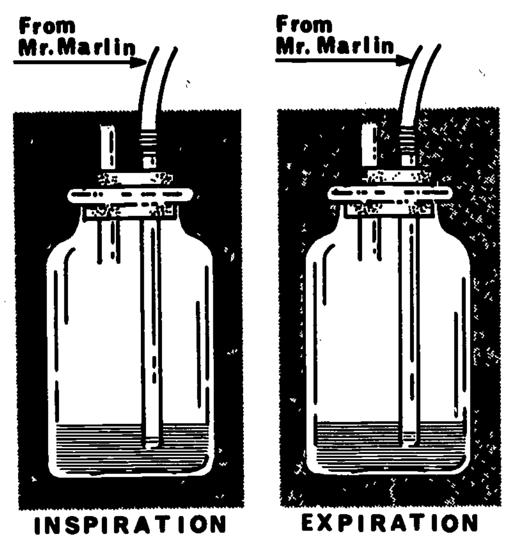
Now, to get back to the water-seal bottle: How can Miss Wilson know whether this apparatus is functioning properly? If you'll remember the pressure changes that occur during respiration, you'll recall that intrapleural pressure falls during inspiration and rises during expiration. As we noted earlier, Mr. Marlin's drainage tubing actually represents an extension of his pleural space. The results of intrapleural pressure changes, therefore, can be seen in the long glass tube which terminates under water.

During inspiration, the lower intrapleural pressure sucks the water a few cm. up into the tube. During expiration, when intrapleural pressure is higher, the water in the tube falls back down into the bottle. This up-and-down movement (fluctuation) of the water in the long glass tube, related to inspiration and expiration, indicates proper functioning of the apparatus.

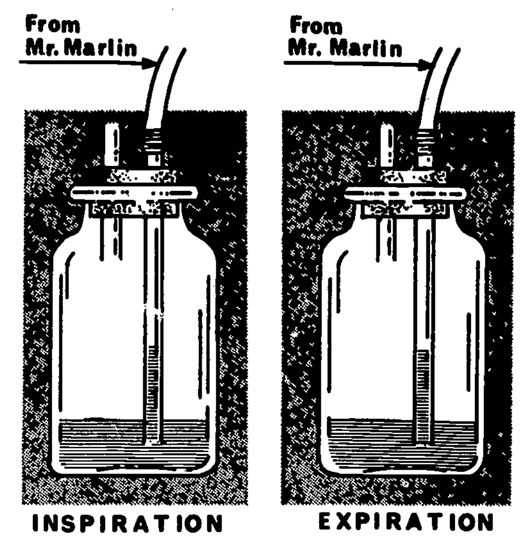
Choose the pair of bottles which illustrates proper functioning of Mr. Marlin's drainage apparatus:



page 146



page 149



page 155

YOUR ANSWER: The patient's catheters should be clamped while replacing the apparatus to prevent fluid from draining onto the floor.

No.

It's true that clamping these catheters would prevent fluid from draining onto the floor, but that's not the reason for doing it. Clamping the catheters does prevent the evacuation of fluid from the pleural space and that's one reason that the apparatus should be replaced as quickly as possible.

Remember that the drainage tubing is an extension of the pleural space. Therefore, air entering the tubing actually is entering the patient's chest.

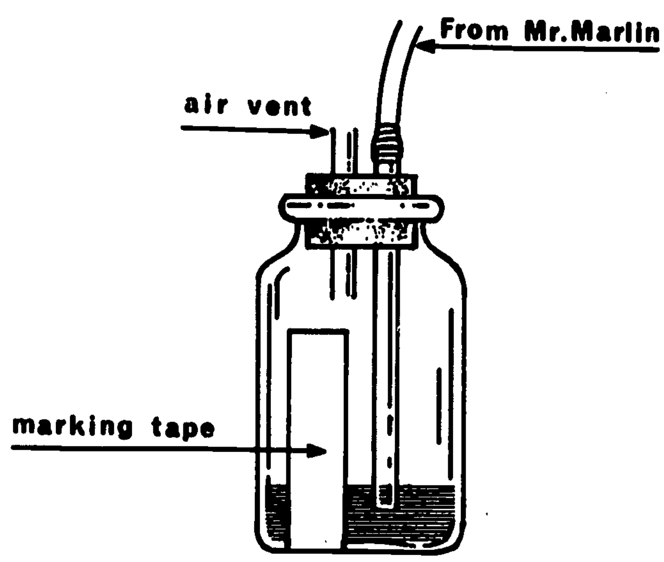
Please RETURN to page 156 and select a better answer.

YOUR ANSWER: The short tube must be open to the atmosphere to permit evacuation of intrapleural air from the bottle.

Right. If there were no air vent, pressure within the bottle would rise and could lead to tension pneumothorax (when we consider the mechanical suction equipment, we'll discuss this again). For now, just remember this: The nurse should make certain that the air vent is kept open to the atmosphere.

Both serosanguinous fluid and air are being evacuated into Mr. Marlin's one-bottle apparatus. We've noted that the air escapes through the air vent; the fluid, however, simply collects in the bottle.

In order to calculate the amount of blood which must be administered to replace blood Mr. Marlin is losing from within his operated chest, Dr. Stone will want to know some things about the fluid collecting in the bottle. He will want to know the amount of blood loss and how fast fluid collects in the drainage apparatus. He will also want to know the character of the drainage, and Miss Wilson should include this in the nurse's notes.



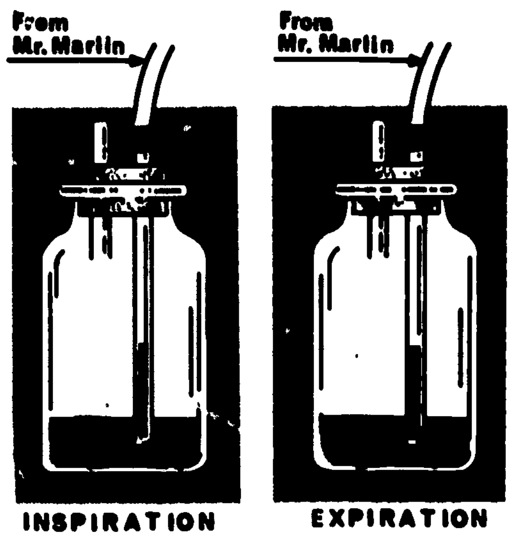
To help Dr. Stone make his calculations, Miss Wilson should keep a record on a strip of marking tape placed on the outside of the bottle as shown in the diagram.

What should Miss Wilson record on the marking tape? (Choose the best answer).

Quantity of blood being lost.	page 151
Quality of the drainage fluid.	page 159
Amount of drainage and rate of flow.	page 162

(*from page 152*)

YOUR ANSWER: This pair of bottles illustrates proper functioning of Mr. Marlin's drainage apparatus:



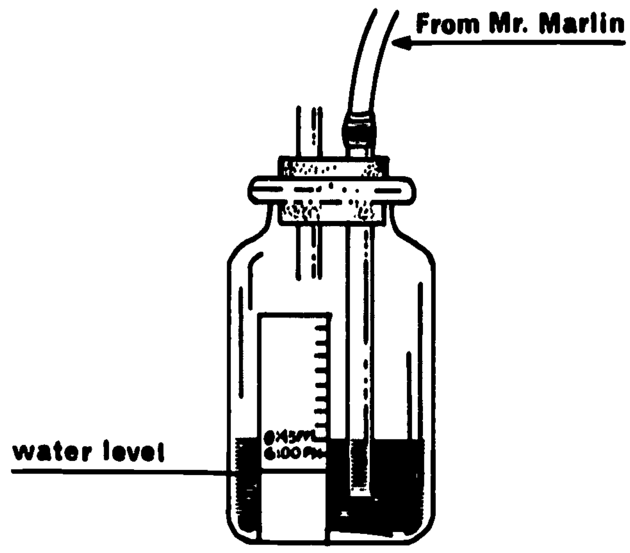
No.

Remember that there should be an up-and-down movement of the water in the long glass tube and that this movement should be related to respiration.

The lower intrapleural pressure during inspiration should pull or suck water a short distance up the glass tube. During expiration, this water should fall back down into the bottle. The rising and falling of intrapleural pressure (during inspiration and expiration) should be reflected in the rising and falling of water in the long glass tube.

Please RETURN to page 152 and select the drawings which represent this fluctuation of the water.

YOUR ANSWER: This tape is properly marked for the one-bottle apparatus:



That's right.

This tape shows the level of the sterile water which was in the bottle at the beginning of therapy; and it shows the time of day that the drainage reached each ensuing level. (Marking the water level also helps to assure that the drainage tube is under water.)

Of course, the bottle must be replaced from time to time. Dr. Stone may wish to do this himself, or he may tell Miss Wilson when to do it. Replacement should be done quickly and cautiously, so that air and fluid don't collect in the pleural cavity and so that the cavity is not exposed to the atmosphere.

Here's the procedure for replacing the one-bottle apparatus:

a. Obtain sterile bottle containing 100 cc. of sterile water.
b. Clamp patient's chest catheters close to the chest.
c. Replace old drainage bottle with the new one.
d. Check system to make sure it's airtight.
e. Unclamp patient's chest catheters.

Why should the patient's catheters be clamped while replacing the apparatus? To prevent:

Fluid from draining onto the floor.	page 153
Air from entering the pleural space.	page 160
Infection of the pleural cavity.	page 166

YOUR ANSWER: The short tube must be open to the atmosphere to prevent atmospheric pressure from entering the bottle.

No, that's not it.

As long as the bottle is open to the atmosphere (as through the short tube), pressure within the bottle will be the same as that in the atmosphere.

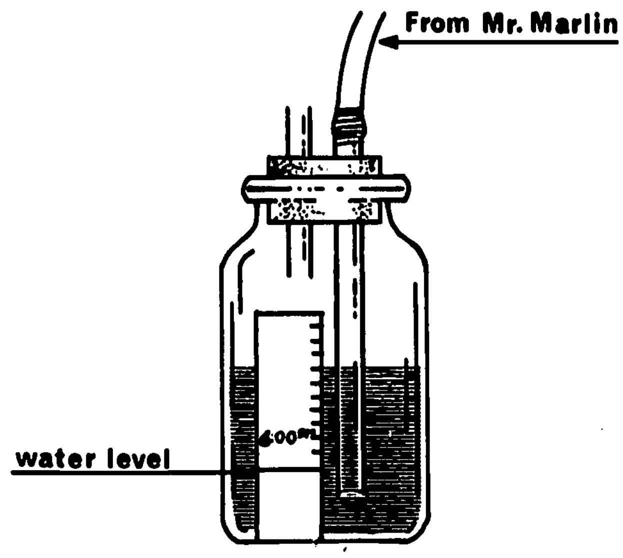
In Section I, we discussed the fact that molecules move to distribute themselves evenly. Because of this characteristic movement, the intrapleural air entering the bottle space from the long glass tube will move out of the bottle into the atmosphere.

If there is no route by which intrapleural air can escape from the bottle, pressure within the bottle will rise. This pressure can become great enough to prevent evacuation of intrapleural air (thus possibly leading to tension pneumothorax).

Please RETURN to page 146 and select the correct answer.

(from page 162)

YOUR ANSWER: This tape is properly marked for the one-bottle apparatus:



Not quite right.

The tape you chose *does* show the water level mark plus the fluid level at six o'clock.

As you can see, however, the level of fluid has risen far beyond that. And no one has noted the time of day on the ensuing level marks.

Please RETURN to page 162 and select the tape that is marked correctly.

YOUR ANSWER: On the marking tape, Miss Wilson should record the quality of the drainage fluid.

No, but she should state this in her nurse's notes.

The record Miss Wilson will keep on the tape affixed to the drainage apparatus will assist Dr. Stone in calculating the volume of blood which should be administered to Mr. Marlin.

When Dr. Stone knows the quantity of serosanguinous fluid which has drained into the bottle—and knows this in relation to time—he will have a basis for calculating the volume of blood which should be replaced.

With this in mind, please RETURN to page 154 and select the best answer.

YOUR ANSWER: The patient's catheters should be clamped while replacing the apparatus to prevent air from entering the pleural space.

Correct. If Mr. Marlin's catheters were not clamped during replacement of the apparatus, his pleural space would again be in contact with the atmosphere through the drainage tubing.

This would be true, too, if Mr. Marlin's one-bottle drainage apparatus should accidentally be broken. Air would enter his pleural space through the drainage tubing. And we know, of course, that exposure of the pleural space to the atmosphere would disrupt therapy. Therefore, all catheters should be clamped immediately whenever air might enter the pleural space through the tubing.

Whenever there's a possibility that the closed pleural space might be opened to the atmosphere, quick action is essential. To be prepared, Miss Wilson should be sure that six- to eight-inch hemostats (two for each catheter) are handy at all times. (If Mr. Marlin is in bed, she should clamp the hemostats to the bottom sheet at the head of the bed. If he's in a wheelchair, she should clamp them to his bathrobe.)

Now here's an easy one: What should Miss Wilson do to be ready for the danger of air entering Mr. Marlin's pleural space?

Place hemostats on his bedside table.	page 163
Tape hemostats to the back of a wheelchair.	page 165
Attach hemostats to his bedding or clothing.	page 169

YOUR ANSWER: To help Mr. Marlin in the situation we've described, Miss Wilson could place additional hemostats on the tubing.

No.

That wouldn't help Mr. Marlin unless Miss Wilson is certain that the drainage tubing is not securely closed by the clamps she has already applied.

If she has indeed stopped leakage of air through the drainage tubing, it appears that Mr. Marlin's symptoms indicate his intrapleural pressure is rising for some other reason. And with the tubing clamped, there is no vent through which this increased pressure can be released.

Since tension pneumothorax can lead to mediastinal shift, it would be better for Mr. Marlin if his intrapleural pressure became atmospheric than if it rose to a dangerous degree.

Please RETURN to page 169 and choose the best answer.

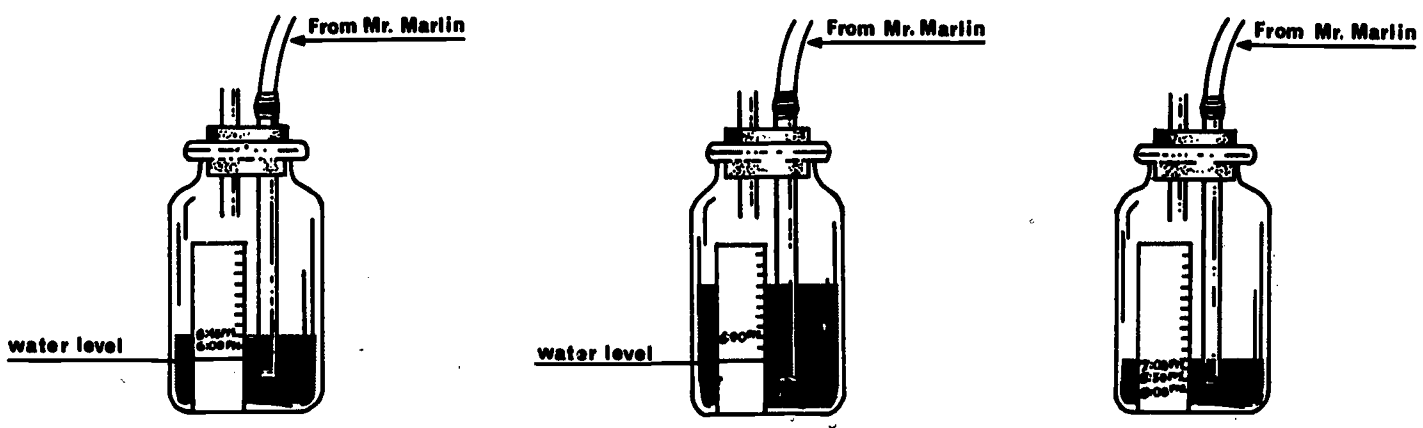
YOUR ANSWER: On the marking tape, Miss Wilson should record the amount of drainage and rate of flow.

You're right; that's the best answer. This information will give Dr. Stone a basis for calculating the volume of blood which should be replaced.

At the beginning of therapy, the one-bottle apparatus should contain about 100 cc. of sterile water. As fluid drains from Mr. Marlin's pleural space, it will mix with this sterile water, thus making measurement of the drainage inexact. Therefore, Miss Wilson should mark the level of the sterile water on the tape before drainage into the bottle begins.

Above the water level mark, "drainage level marks" should be placed on the tape, with each of these marks representing approximately 100 cc. of drainage. As the fluid level in the bottle rises and reaches the next "drainage level mark," Miss Wilson should record the time of day on the tape beside that mark.

Choose the tape which is properly marked for the one-bottle apparatus:



page 156　　page 158　　page 164

YOUR ANSWER: To be ready for the danger of air entering Mr. Marlin's pleural space, Miss Wilson should place hemostats on his bedside table.

That's not enough.

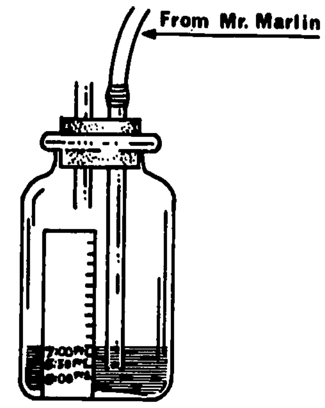
Things placed on a bedside table often "walk off by themselves."

If Mr. Marlin's tubing is accidentally exposed to the air, it must be closed immediately. To assure that hemostats are available if needed, they should be located so that they are with the patient at all times.

Please RETURN to page 160 and choose a better answer.

(from page 162)

YOUR ANSWER: This tape is properly marked for the one-bottle apparatus:



No.

Remember that the one-bottle apparatus contains sterile water at the beginning of therapy. The level of this water should be marked on the tape so that the drainage which flows into the bottle can be measured more accurately.

Please RETURN to page 162 and select the tape that is marked correctly for the one-bottle apparatus.

YOUR ANSWER: To be ready for the danger of air entering Mr. Marlin's pleural space, Miss Wilson should tape hemostats to the back of a wheelchair.

Just any old wheelchair?

That wouldn't be much protection for Mr. Marlin unless it was a wheelchair he was sitting in, would it?

The idea is that the hemostats should be located so that they are with Mr. Marlin at all times. His drainage tubing must be closed immediately if it accidentally becomes exposed to the air.

Please RETURN to page 160 and choose a better answer.

YOUR ANSWER: The patient's catheters should be clamped while replacing the apparatus to prevent infection of the pleural cavity.

No, that's not the reason for clamping the catheters. However, it's true that the system should be kept sterile.

If you'll remember that the drainage tubing is an extension of the pleural space and that air entering this tubing actually is entering the patient's chest, you'll understand the reason for clamping the patient's chest catheters in this situation.

Please RETURN to page 156 and select the right answer.

YOUR ANSWER: To help Mr. Marlin in the situation we've described, Miss Wilson could obtain the fresh apparatus herself.

Not exactly.

(She might, however, have had an extra one handy in case of an emergency like this.)

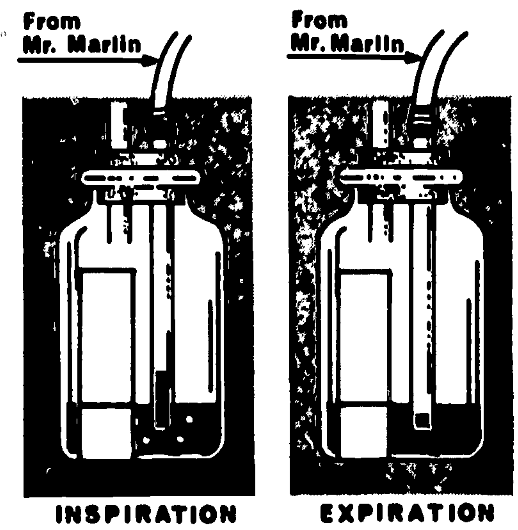
The point here is this: Although we've said that generally the patient's drainage tubing should be closed immediately if it is accidentally opened to the air, there *are* situations where clamping the tubing can do more harm than good.

If the tubing is securely closed and there are signs of possible tension pneumothorax with resultant mediastinal shift, the tubing should be opened. Since mediastinal shift can cause death within a short time, it would be better to allow intrapleural pressure to become atmospheric than to permit it to rise to a dangerous degree.

Please RETURN to page 169 and choose the best answer.

(from page 172)

YOUR ANSWER: This pair of bottles illustrates that air is leaking into the drainage apparatus:



Not necessarily.

It's true that some bubbling may appear in the water, especially during the immediate postoperative period. Remember that intrapleural air is evacuated through the long glass tube—and it may bubble out through the water. Such bubbling will be intermittent, however.

If bubbling in the water-seal bottle is *continuous,* this indicates an air leak. Air may be leaking through an opening somewhere in the drainage apparatus.

Please RETURN to page 172 and select a better answer.

YOUR ANSWER: To be ready for the danger of air entering Mr. Marlin's pleural space, Miss Wilson should attach hemostats to his bedding or clothing.

Right. If Mr. Marlin's drainage tubing is accidentally opened to the air, it must be closed immediately. Miss Wilson should make certain that the hemostats are always with Mr. Marlin. (And the best time to clamp the tubing is following an expiration.)

Although what we've just said about clamping the tubing is true, *in some cases* it would be best to leave the drainage tubing open to the atmosphere. For example, when there is leakage of air through the sutured area on the lung, clamping the drainage tubing could result in increased intrapleural pressure which could lead to tension pneumothorax and finally to mediastinal shift.

Now consider this situation: Suppose that the drainage apparatus is accidentally broken. Immediately, Miss Wilson clamps her patient's two chest catheters following an expiration. While she waits for another apparatus, she notes that Mr. Marlin is in distress. His skin is blue and his breathing is shallow and rapid. Aside from calling for a physician, what could she do to help Mr. Marlin?

Place additional hemostats on the tubing. page 161
Obtain another apparatus herself. page 167
Unclamp the chest catheters. page 172

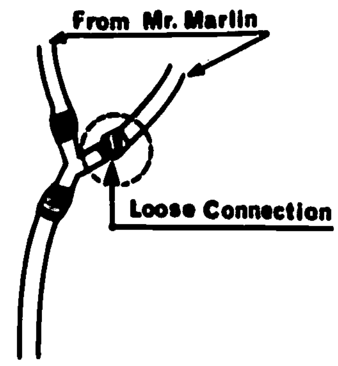
(from page 175)

YOUR ANSWER: If Miss Wilson sees continuous bubbling in Mr. Marlin's water-seal bottle, she should locate the source of leakage and repair it if possible.

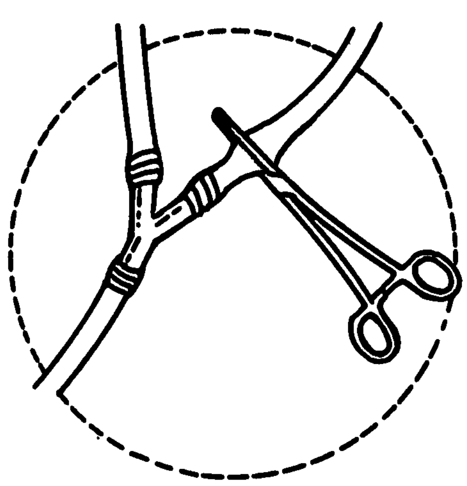
Of course. She should try to find and repair the leak. In searching for an air leak, Miss Wilson should check the insertion of the catheters in the chest wall first. If a catheter is loose, squeezing the skin up and around it will stop the continuous bubbling. (Application of vaseline gauze around the insertion may repair the leak.) If neither catheter is loose and there is no visible defect in the tubing or connections, it may be necessary to replace the drainage apparatus with a new one.

Although we're not quite ready for a detailed description of the mechanical suction equipment, we're going to skip ahead for a moment — to discuss a way to locate an air leak when it occurs in a motorized system. (For the time being, simply accept the fact that there would be a water-seal bottle in a mechanical suction system.)

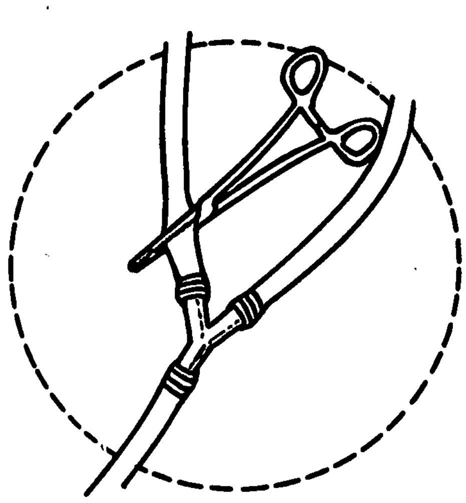
As described above for the simple water-seal system, a loose catheter is the first thing to look for. If a catheter is not loose and there are no visible defects in the mechanical suction system, the nurse should clamp the tubing briefly, beginning at the end of the chest catheter and working downward toward the apparatus. If the leak is located between the end of the catheter and the water-seal bottle, clamping the tubing between the leak and this bottle will cause the bubbling in the bottle to cease. (Application of tape may repair the leak. *For prevention, tape all connections.*)



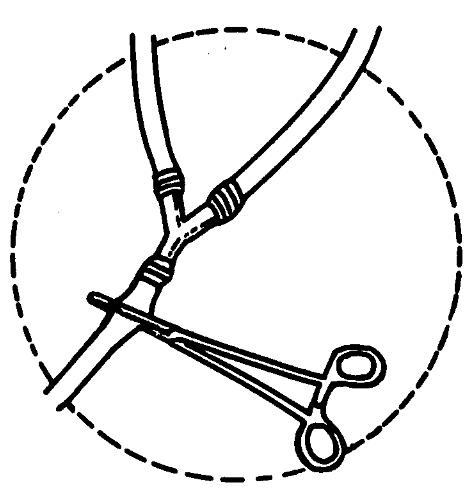
Now suppose that air is leaking into a mechanical suction apparatus through the loose connection indicated in the above drawing. Which of the clamps shown below would stop the constant bubbling in the water-seal bottle?



page 174



page 181



page 183

(from page 183)

YOUR ANSWER: (a) "Absence of drainage" and (b) "Absence of fluctuation in the water-seal bottle" would tell Dr. Stone that all intrapleural fluid and air have been evacuated.

Not exactly.

You're right about (b). The absence of fluctuation in the water-seal bottle *is* a sign that evacuation of intrapleural fluid and air has been completed. However, it is also a sign that the apparatus is not functioning properly. Therefore when this fluctuation ceases and the physician believes the lung has been re-expanded, he will want to confirm it by seeing it on a chest x-ray.

Absence of drainage is *not* a reliable sign that complete evacuation has been accomplished; for example, drainage might cease because of obstructed tubing.

Please RETURN to page 183 and choose the correct answer.

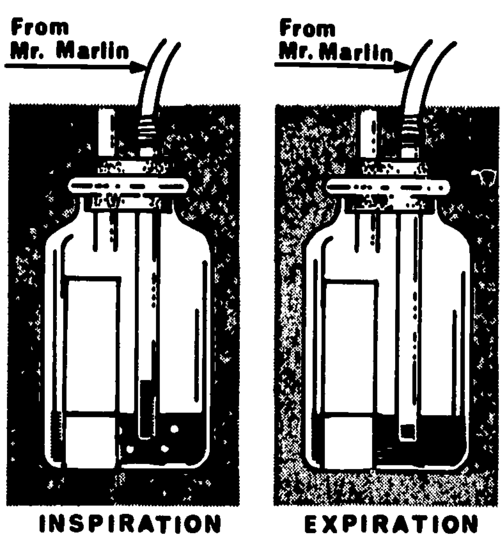
YOUR ANSWER: To help Mr. Marlin in the situation we've described, Miss Wilson could unclamp the chest catheters.

You're right. Since mediastinal shift can cause death rapidly, it would be better to allow intrapleural pressure to become atmospheric than to permit it to rise to a dangerous degree. This action would require careful judgment. But if the nurse had to deal with this special situation, she could release the clamps on the catheters if signs of tension pneumothorax (and/or mediastinal shift) appeared.

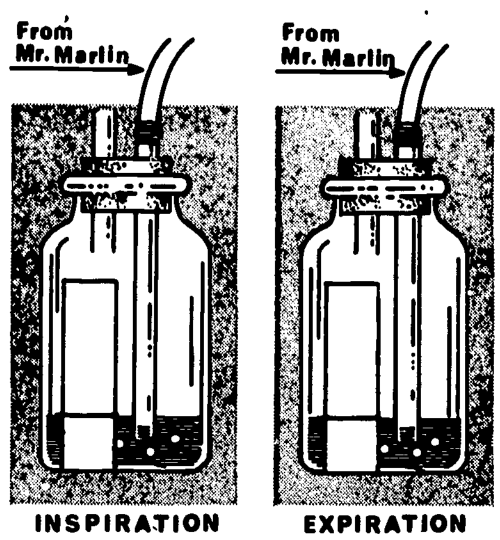
Bubbling is another thing to watch for in the water-seal apparatus. Bubbling in the liquid in this bottle may occur intermittently or constantly. If the bubbling is intermittent (especially during the immediate postoperative period), there's no need for concern. Particularly when the patient coughs or breathes deeply, intrapleural air will be pushed out through the tubing—and it may bubble out.

Continuous bubbling is another thing. It indicates leakage of air into the drainage system.

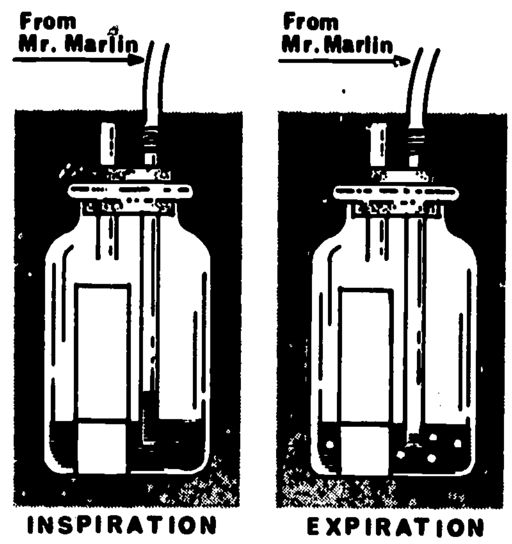
Which of the following pairs of bottles illustrates that air is leaking into the drainage apparatus?



page 168



page 175



page 178

(from page 175)

YOUR ANSWER: If Miss Wilson sees continuous bubbling in Mr. Marlin's water-seal bottle, she should tape his drainage tubing to the under-water tube.

Not exactly.

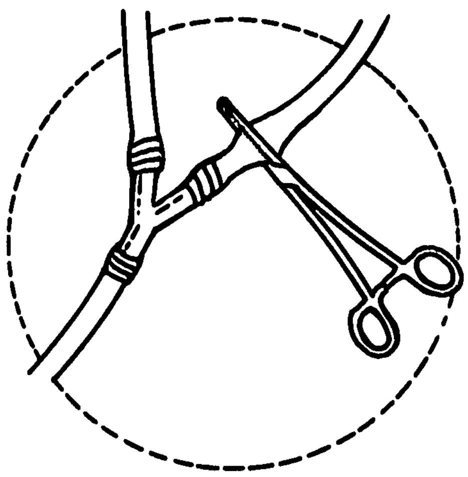
At least, she should have done that when the drainage tubing was first connected to the underwater tube. If you'll recall, we recommended some time back that *all* points of connection be taped routinely.

The situation we're dealing with now involves an air leak. In other words, it's too late to *prevent* an air leak. Continuous bubbling in the water-seal bottle indicates that we have one. What should Miss Wilson do about it?

Please RETURN to page 175 and select a better answer.

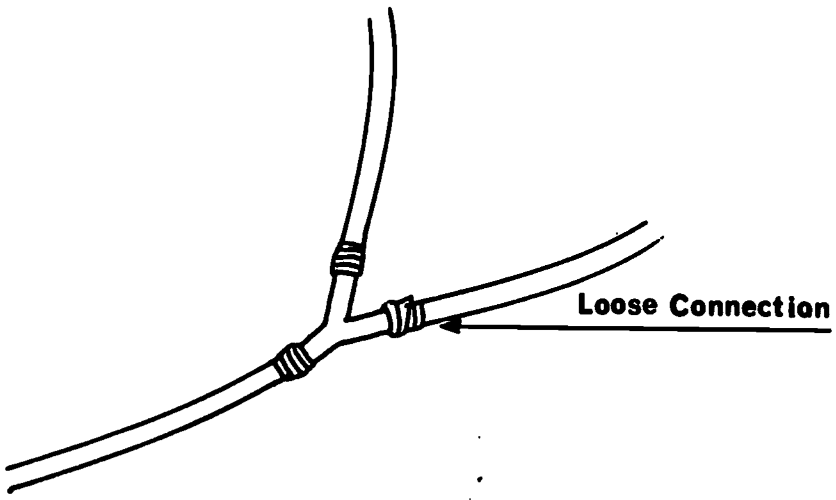
(from page 170)

YOUR ANSWER: This clamp would stop the constant bubbling in the water-seal bottle:



No, it wouldn't.

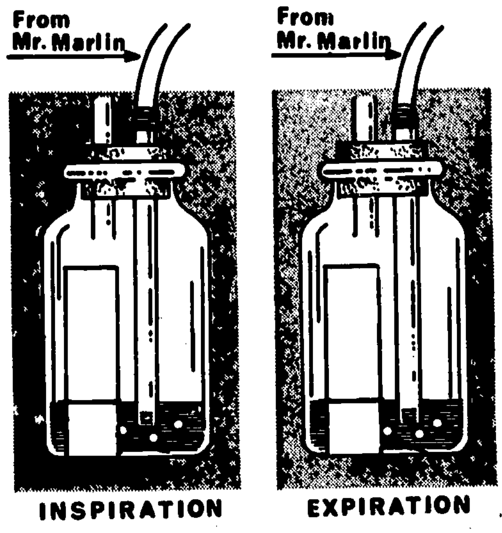
Here again is the connection we said was loose:



Remember that clamping the tubing at a place which is *between* the air leak and the water-seal bottle will cause the bubbling to cease. (And remember also that we're describing a procedure for locating an air leak in a mechanical suction system.)

Please RETURN to page 170 and select the correct drawing.

YOUR ANSWER: This pair of bottles illustrates that air is leaking into the drainage apparatus:



Correct. While *intermittent* bubbling is to be expected (especially in the immediate postoperative period), *continuous* bubbling indicates an air leak in the drainage system.

Since we know that air leaking into the drainage apparatus (therefore into the pleural space) prevents successful re-expansion of the lung, the nurse should watch the water-seal bottle for the appearance of constant bubbling.

As we said, intermittent bubbling indicates that intrapleural air is being evacuated. Suppose, however, that Miss Wilson observes continuous bubbling in Mr. Marlin's water-seal apparatus. (Perhaps she hasn't paid attention to one of our earlier suggestions, which was that all connecting points should be taped.)

Use your good judgment in answering this question: If Miss Wilson sees continuous bubbling in Mr. Marlin's water-seal bottle, what should she do?

Locate the source of leakage and repair it if possible.	page 170
Tape Mr. Marlin's drainage tubing to the under-water tube.	page 173
Assume that air is leaking through the sutured lung surface.	page 179

YOUR ANSWER: The mechanical suction apparatus "does the job" faster than the simple water-seal by permitting the drainage of intrapleural fluid.

Not exactly.

Drainage would take place anyway, as long as the drainage apparatus is at a level lower than the patient's chest and the tubing is patent.

The point is that the suction motor speeds up the evacuation of fluid and air by actually drawing it out from the pleural space. It does this by creating and maintaining negative pressure (which has a sucking effect) throughout the closed drainage system.

Please RETURN to page 188 and choose the right answer.

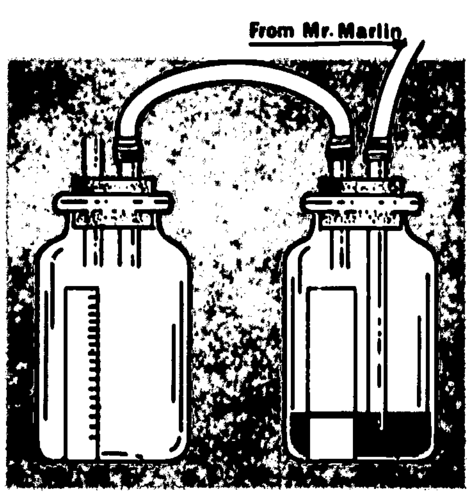
YOUR ANSWER: (b) "Absence of fluctuation in the water-seal bottle" and (c) "Evidence shown on a chest x-ray" would tell Dr. Stone that all intrapleural fluid and air have been evacuated.

Correct. When cessation of fluctuation indicates that Mr. Marlin's lung *may* have re-expanded, Dr. Stone will confirm it by x-ray.

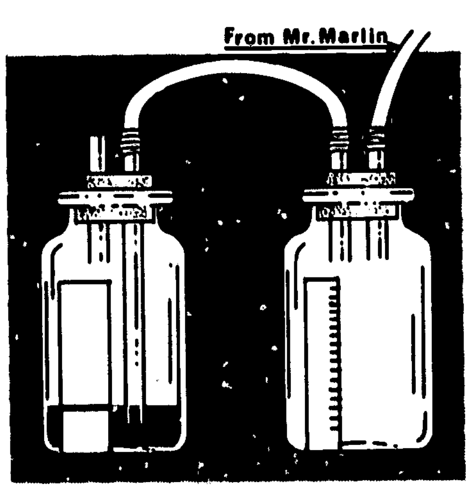
Here's something else about water-seal drainage: Frequently a separate bottle is used to collect the drainage fluid. In the two-bottle set-up, the water-seal bottle looks almost the same as before. Only two things are different: (1) the under-water tube is connected to the drainage bottle rather than to the patient's tubing and (2) only the water level is marked on the outside tape. A tape for recording quantity and rate of drainage is applied to the drainage bottle.

The empty drainage bottle is closed by a tight-fitting rubber stopper taped in place. This stopper contains two short hollow glass or metal tubes, both of which extend about one inch into the bottle. One of these tubes is connected to the patient's tubing, while the other is joined to the long under-water tube.

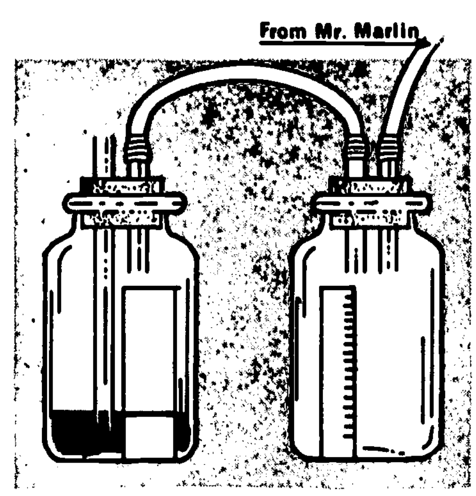
Which of the following represents the two-bottle water-seal system we've described?



page 182



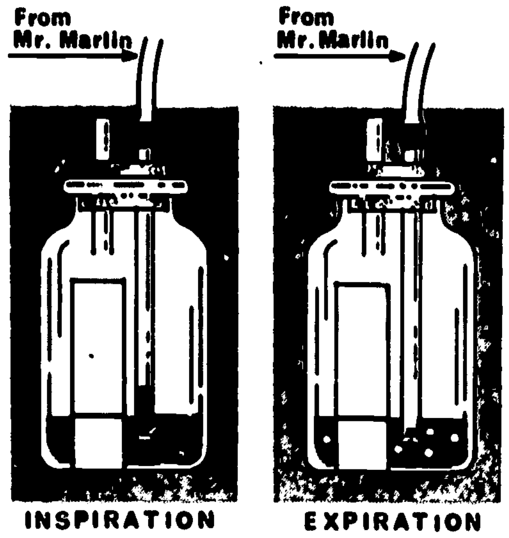
page 186



page 189

(from page 172)

YOUR ANSWER: This pair of bottles illustrates that air is leaking into the drainage apparatus:



Not necessarily.

It's true that some bubbling may appear in the water, especially during the immediate postoperative period. If this bubbling is *intermittent,* it is an indication that intrapleural air is being evacuated through the long glass tube.

If bubbling in the water-seal bottle is continuous, however, this indicates an air leak. Air may be leaking through an opening somewhere in the drainage apparatus.

Please RETURN to page 172 and select a better answer.

YOUR ANSWER: If Miss Wilson sees continuous bubbling in Mr. Marlin's water-seal bottle, she should assume that air is leaking through the sutured lung surface.

No.

If air were leaking into the pleural cavity through the opening in the pulmonary pleura and the apparatus were functioning properly, this air should be evacuated through the long glass tube. And it might bubble out intermittently through that tube.

The situation we've described involves constant bubbling, an indication of air leaking into the drainage system. Use your judgment in deciding what Miss Wilson should do in this situation.

Please RETURN to page 175 and select the best answer.

(from page 183)

YOUR ANSWER: (c) "Evidence shown on an x-ray" and (d) "Intermittent bubbling in the water-seal bottle" would tell Dr. Stone that all intrapleural fluid and air have been evacuated.

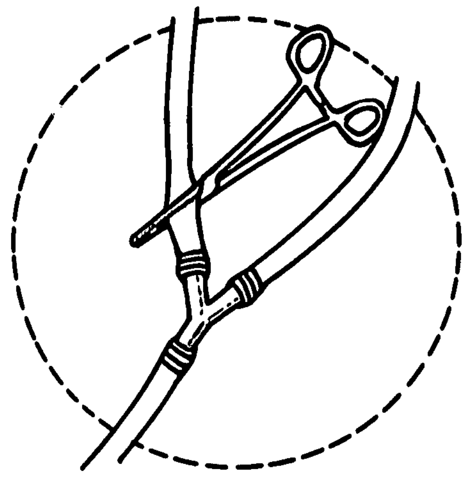
Not quite right.

You're right about (c). If the physician suspects that complete evacuation has been accomplished, he will want to confirm it. And to confirm it, he will order a chest x-ray, which will show whether or not the lung has actually re-expanded.

As we noted earlier, intermittent bubbling in the water-seal bottle indicates that air is being evacuated from the pleural space. When all movement of air in the water-seal bottle ceases, *that* is a sign that evacuation of fluid and air *may* be complete.

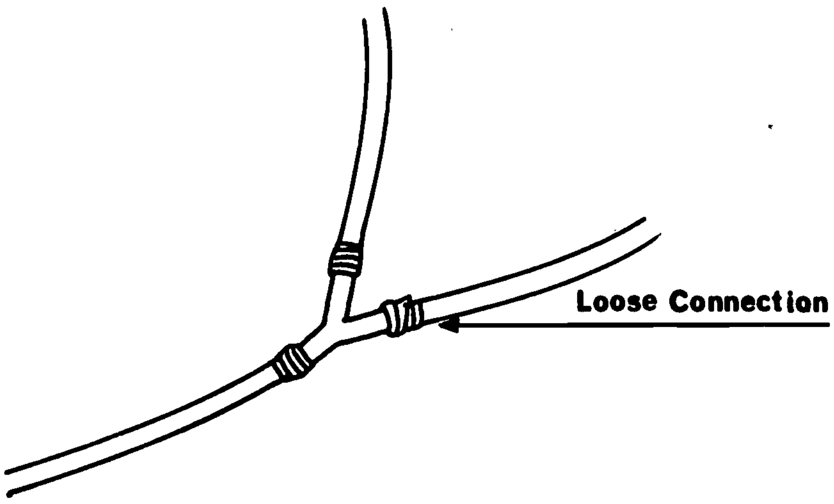
Please RETURN to page 183 and choose the correct answer.

YOUR ANSWER: This clamp would stop the constant bubbling in the water-seal bottle:



Wrong.

Here again is the connection we said was loose:



Remember that clamping the tubing at a place which is *between* the air leak and the water-seal bottle will cause the bubbling to cease. (And remember also that we're describing a procedure for locating an air leak in a mechanical suction system.)

Please RETURN to page 170 and select the correct drawing.

(from page 177)

YOUR ANSWER: This diagram represents the two-bottle water-seal system we've described:

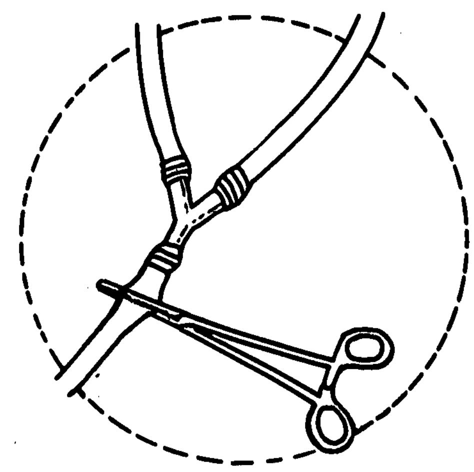
Wrong.

In the diagram you chose, the proper position of these two bottles is reversed. If the bottles were in this position, collection of the drainage in a separate empty bottle would be impossible. (Study the diagram until you see that.) Everything else about this drawing is correct.

Remember that in the two-bottle set-up, the patient's drainage tubing is connected to the empty drainage bottle.

Please RETURN to page 177 and choose the correct answer.

YOUR ANSWER: This clamp would stop the constant bubbling in the water-seal bottle:



Right. In a mechanical suction system, clamping the tubing at a place which is *between* the air leak and the water-seal bottle would cause the bubbling to stop, thus pinpointing the source of leakage. Remember that it is constant bubbling in the water-seal bottle which signifies air leakage both in the simple water-seal and mechanical suction systems.

Now to return to the water-seal apparatus: We noted earlier that a characteristic up-and-down fluctuation of water in the long glass tube indicates proper functioning of the simple water-seal apparatus. If this fluctuation ceases, it can mean that the apparatus is not working properly — or that evacuation of intrapleural fluid and air has been completed.

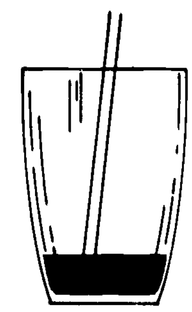
Generally, it takes from 24 to 72 hours after surgery to restore normal respiration. When this has been accomplished, lung tissue blocks the catheter openings in the pleural space; and fluctuation in the water-seal bottle ceases. When fluctuation ceases, the only reliable way to confirm the re-expansion of Mr. Marlin's lung is by x-ray. If the lung *has* re-expanded, Dr. Stone will remove the catheters and close the wound edges with tight adhesive dressings, thus completing closed drainage of the chest.

What two signs would tell Dr. Stone that all intrapleural fluid and air have been evacuated? (Choose the correct pair.)

a. Absence of drainage.
b. Absence of fluctuation in the water-seal bottle.
c. Evidence shown on a chest x-ray.
d. Intermittent bubbling in the water-seal bottle.

a. and b. page 171
b. and c. page 177
c. and d. page 180

YOUR ANSWER: This glass is the one into which a person would have to blow hardest in order to make bubbles in the water:



No.

Blowing bubbles in the glass you chose would require less pressure than in either of the other glasses we showed you. The reason is that there's less water in the glass you chose, and therefore there's less water inside the straw in that glass. Blowing bubbles through that straw would be considerably easier than if the glass (and straw) were full of water.

The same idea can be applied to the water-seal bottle. It requires more pressure to force down the fluid in the under-water tube when the tube is relatively full of fluid. This is an important reason that drainage often is collected in a separate bottle.

Please RETURN to page 186 and choose the right answer.

YOUR ANSWER: The mechanical suction apparatus "does the job" faster than the simple water-seal by applying a constant amount of suction to the pleural space.

That's right. The suction motor creates and maintains negative pressure throughout the closed drainage system. (It does this by constantly evacuating air from within the system, thus increasing the capacity of the system. Remember that as the capacity of a container increases, pressure within it falls.) Negative pressure created by the motor pulls fluid and air from Mr. Marlin's pleural space.

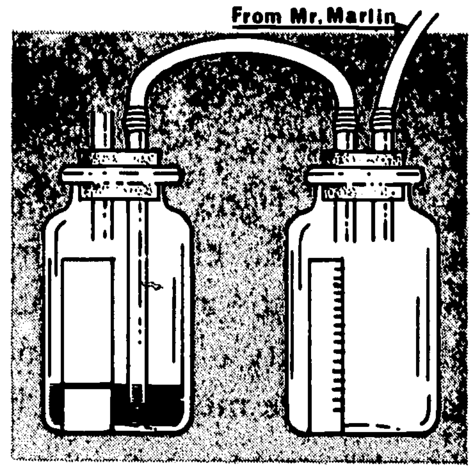
Now the amount of suction which is applied to Mr. Marlin's pleural space must be controlled, since too much suction would damage his lung tissue. Most suction motors do indeed create too much suction for this purpose.

It is necessary, therefore, for the mechanical suction apparatus to include a device which will control the degree of negative pressure (suction) in the drainage system (and in the pleural space). In the manufactured apparatus we mentioned earlier, generally a built-in "meter" takes care of this. In Mr. Marlin's apparatus, the third bottle is the control device.

What is the purpose of the third bottle in Mr. Marlin's mechanical suction system?

It controls the suction motor. page 187
It creates negative pressure in the pleural space. page 197
It regulates the amount of pressure in the system. page 199

YOUR ANSWER: This diagram represents the two-bottle water-seal system we've described:



Very good. The patient's drainage tubing is attached to the empty drainage collection bottle, and the drainage bottle is connected to the under-water tube.

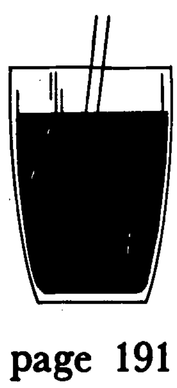
Since the two-bottle water-seal system is so similar to the one-bottle, you may be wondering why two bottles are frequently used. Here are some reasons:

As the fluid level in the one-bottle apparatus rises, it becomes more difficult to evacuate intrapleural air through the under-water tube. When the level of fluid in this tube is high, it requires more pressure to force it down. (The more fluid in the bottle, the more there is in the under-water tube.)

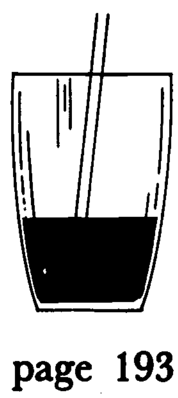
Another reason for using two bottles involves measurement and other characteristics of the drainage fluid. This fluid can be measured more accurately and its color and character can be seen more clearly when it drains into a separate bottle.

The drinking glasses shown below contain liquid and straws. Choose the one into which a person would have to blow hardest in order to make bubbles in the water.

page 184



page 191



page 193

YOUR ANSWER: The purpose of the third bottle in Mr. Marlin's mechanical suction system is to control the suction motor.

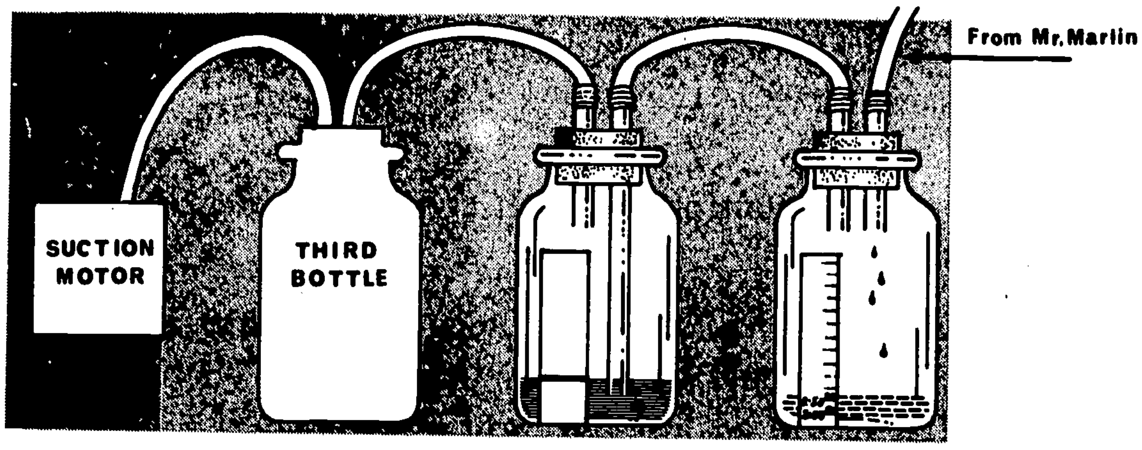
Not exactly.

This bottle, however, *is* a control device. It controls the degree of negative pressure in the drainage system.

Most suction motors create a degree of negative pressure (suction) which, if applied to the pleural space, would damage the lung tissue. Therefore, this pressure must be modified so that it will be just the right amount.

Please RETURN to page 185 and choose a better answer.

YOUR ANSWER: This diagram represents Mr. Marlin's mechanical suction device:



Very good. The drainage and water-seal bottles are connected to each other as before. And the third bottle is connected to the former "air vent" on the water-seal bottle and to the suction motor.

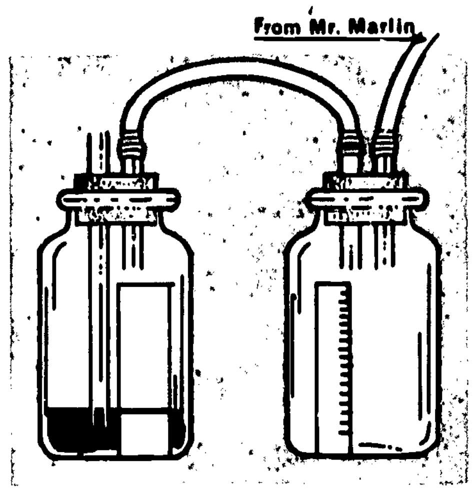
We noted that a mechanical suction apparatus will evacuate intrapleural fluid and air faster than the simple water-seal device. Instead of depending on a gradual evacuation of fluid and air and re-apposition of the pleurae, the suction motor actively pulls fluid and air from the pleural space. It creates and maintains a certain degree of negative pressure (suction) within Mr. Marlin's pleural space as well as throughout the closed drainage system.

Just as the motor in a vacuum cleaner creates suction which pulls dust and dirt from a rug, the motor in the mechanical suction apparatus creates suction which pulls fluid and air from Mr. Marlin's pleural space.

How does the mechanical suction apparatus "do the job" faster than the simple water-seal?

By permitting the drainage of intrapleural fluid. page 176
By applying a constant amount of suction to the pleural space. page 185
By allowing the development of negative intrapleural pressure. page 190

YOUR ANSWER: This diagram represents the two-bottle water-seal system we've described:



Wrong.

Perhaps you've forgotten the purpose of the water in the water-seal bottle?

Maybe it will help to think of it this way: In a closed drainage system, the patient's pleural space extends to the point where it is "sealed" by the water in the water-seal bottle. In other words, the patient's drainage tubing, the interior of the drainage bottle, and the tubing which joins the two bottles—all represent an extension of the pleural space. Therefore, in the diagram you chose, the patient's pleural space would be exposed to the air in the water-seal bottle instead of being "sealed" by the water in that bottle.

Please RETURN to page 177 and select the correct answer.

(from page 188)

YOUR ANSWER: The mechanical suction apparatus "does the job" faster than the simple water-seal by allowing the development of negative intrapleural pressure.

Not exactly.

That is more or less what happens with the simple water-seal apparatus, i.e., as intrapleural air is evacuated, negative intrapleural pressure gradually returns to its "normal" degree.

In the mechanical suction apparatus, the suction motor speeds up the evacuation of fluid and air by actually drawing it out from the pleural space. It does this by creating and maintaining negative pressure (which has a sucking effect) throughout the closed drainage system.

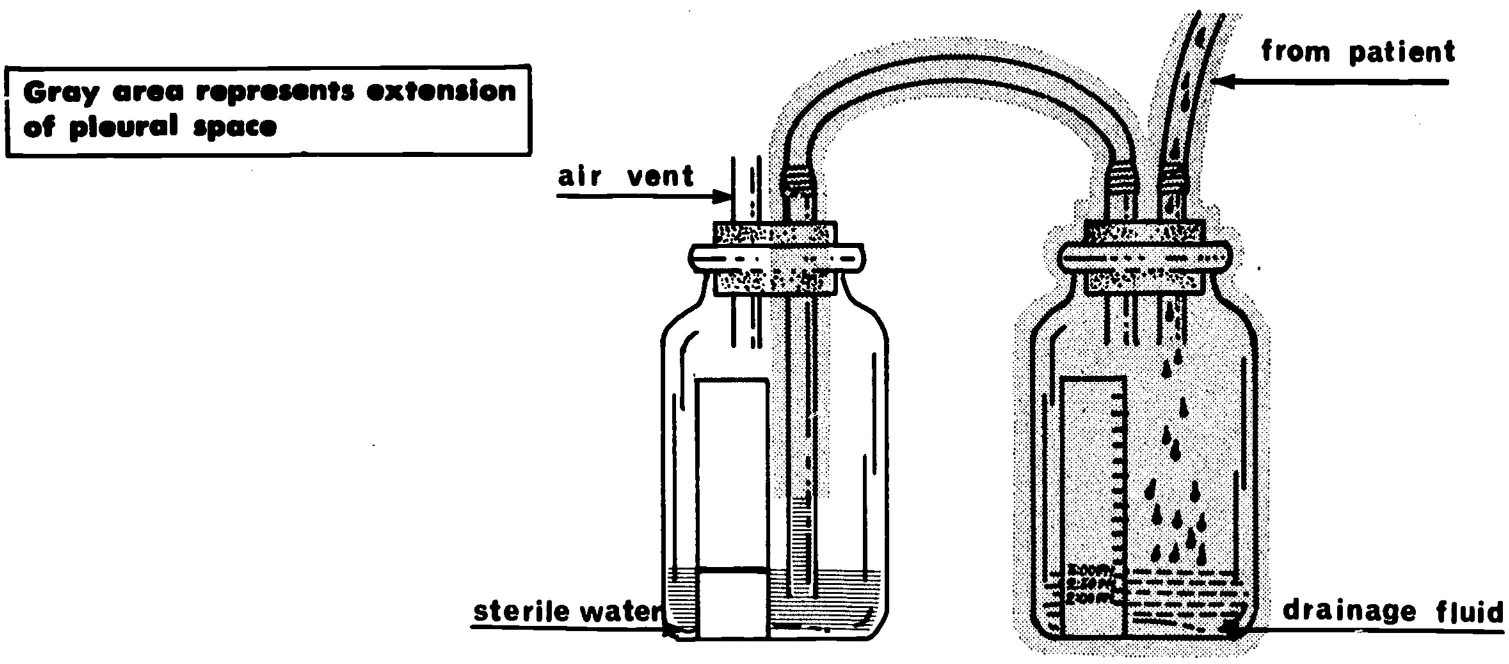
Please RETURN to page 188 and choose the correct answer.

YOUR ANSWER: This glass is the one into which a person would have to blow hardest in order to make bubbles in the water:

Right. And it requires more pressure to force down the fluid in the under-water tube when the tube is relatively full of fluid. This is an important reason that drainage often is collected in a separate bottle.

Except for this collection of drainage in a separate bottle, the one- and two-bottle water-seal systems do exactly the same job and do it in the same way. (The patient's pleural space extends to the point where water "seals" it; intrapleural air escapes via the air vent; up-and-down movement of fluid in the under-water tube indicates proper functioning.)

Here's a diagram showing the two-bottle system functioning during inspiration:



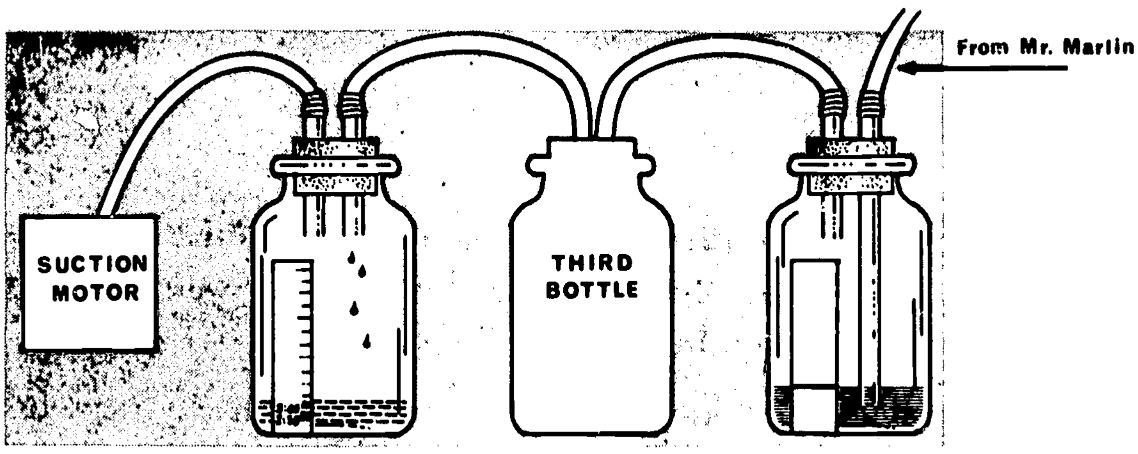
INSPIRATION

We've discussed a number of important ideas to guide the nurse in taking care of a patient being treated by closed chest drainage. All of these ideas apply to drainage with the above two-bottle apparatus as well as to treatment with the simpler one-bottle system.

Please turn to page 194.

(from page 196)

YOUR ANSWER: This diagram represents Mr. Marlin's mechanical suction device:



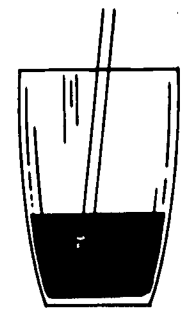
Wrong.

Remember that the patient's drainage collection bottle *must* be connected to his drainage tubing. Otherwise, it would be impossible for the drainage to collect in the proper bottle.

Please RETURN to page 196 and read the information again before selecting the correct diagram.

(from page 186)

YOUR ANSWER: This glass is the one into which a person would have to blow hardest in order to make bubbles in the water:



Not quite.

We're drawing an analogy between blowing bubbles into a drinking glass containing liquid and pushing intrapleural air out through the under-water tube. We said that it requires more pressure to force down the fluid in the under-water tube when the tube is relatively full of liquid.

Remember that the more fluid in the bottle (or glass), the more there is in the under-water tube (straw). This is an important reason that drainage often is collected in a separate bottle.

Please RETURN to page 186 and choose the right answer.

(from page 191)

To help you remember these important "guides," let's take a moment to read them again:

1. *Keep the drainage apparatus at a level lower than the patient's chest at all times.*
2. *Check the drainage tubing regularly for patency.*
3. *"Milk" the drainage tubing about once an hour to prevent clogging.*
4. *Observe the drainage tubing to make certain it is airtight.*
5. *Watch the patient for signs of tension pneumothorax and mediastinal shift.*
6. *If tension pneumothorax develops, call a physician immediately!*
7. *Simple water-seal apparatus: observe water for fluctuation which indicates proper functioning.*
8. *Simple water-seal apparatus: make certain the air vent is open to the atmosphere.*
9. *Record quantity and rate of drainage accurately.*
10. *Clamp all catheters immediately whenever air might enter pleural space through tubing.*
11. *Keep hemostats with the patient at all times.*
12. *Release clamps on catheters if signs of tension pneumothorax and/or mediastinal shift appear.*
13. *Simple water-seal apparatus: observe water for constant bubbling.*
14. *Simple water-seal apparatus: if bubbling is continuous, locate air leak and repair if possible.*

Now we're almost ready to talk about the mechanical suction equipment. Please go on to page 195.

(from page 194)

Before we describe the appearance of the mechanical suction apparatus, we want to emphasize the following: So far, we've discussed 14 important ideas to guide the nurse in her care of the patient on a closed chest drainage apparatus. Twelve of these "guides" apply to drainage with the mechanical suction apparatus as well as to the simple water-seal system. Only two of them pertain solely to drainage with the water-seal apparatus: (a) Observe water for fluctuation which indicates proper functioning and (b) Make certain the air vent is open to the atmosphere.

Although the mechanical suction equipment does include a "water-seal bottle," in this case the water in that bottle generally does not fluctuate and the air vent usually is not open to the atmosphere. As we discuss the mechanical suction equipment, we will add a few "guides" which pertain only to this type of apparatus.

Now we'll return to the operating room where Mr. Marlin's lung was resected. We'll imagine that Dr. Stone has decided to connect Mr. Marlin's tubing to a mechanical suction device rather than to the simple water-seal apparatus.

There are various reasons for his decision. One might be that Dr. Stone wants to hasten evacuation of the intrapleural fluid and air; another might be that there is considerable leakage of air through the cut pulmonary pleura. But the reason for Dr. Stone's decision is not really our concern; so let's go on now to consider the appearance of this suction apparatus.

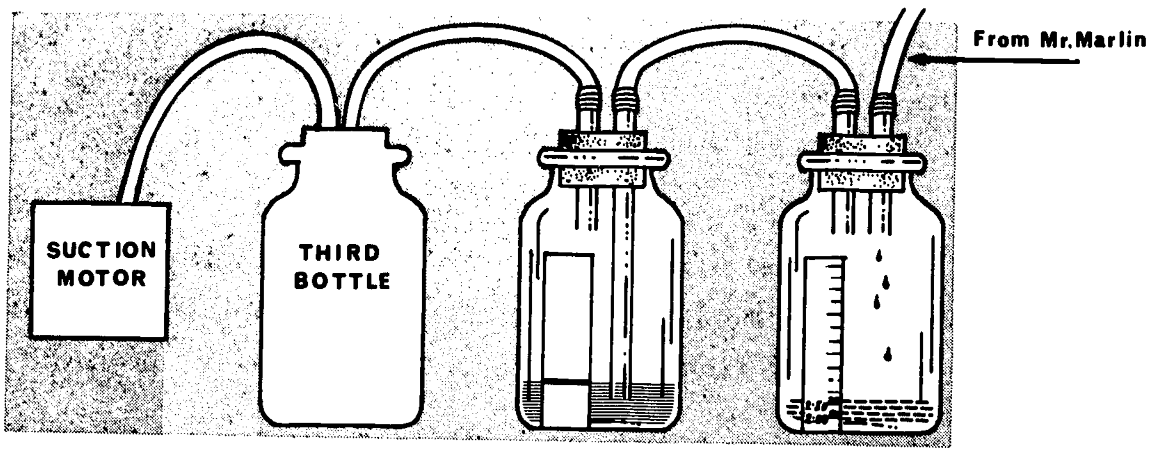
Please go on to page 196.

(from page 195)

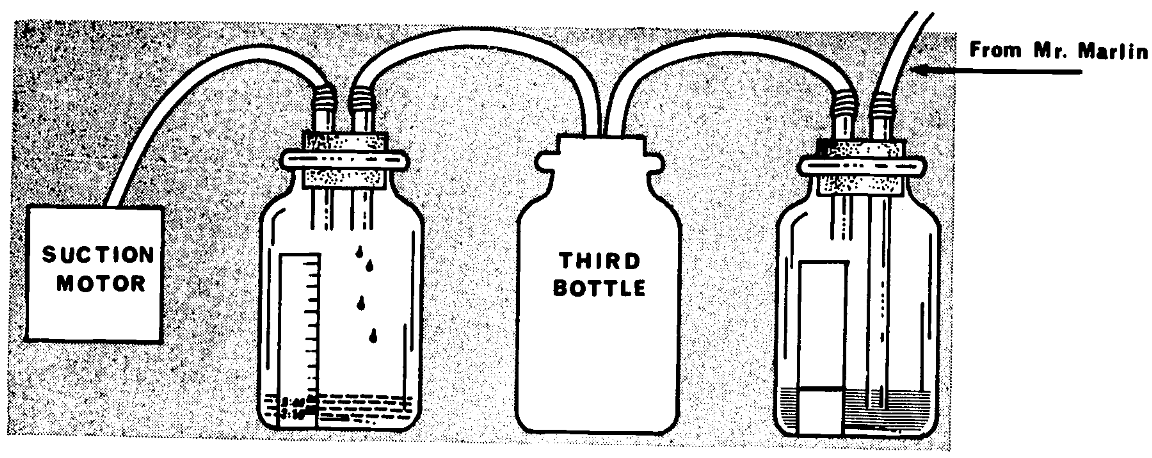
We're ready to take a look at Mr. Marlin's mechanical suction device: It includes the same two bottles we've discussed earlier — the drainage collection bottle (attached to the patient's tubing) and the water-seal bottle. It also includes a third bottle, connected to the former "air vent" on the water-seal bottle. We'll explain the third bottle soon.

In addition, the apparatus includes a suction motor, which is accessible via an outlet in the wall. (Some companies manufacture an apparatus with built-in suction motor. Specific details of operation may be different for each of these, so the nurse should check the brochure which accompanies the machine.)

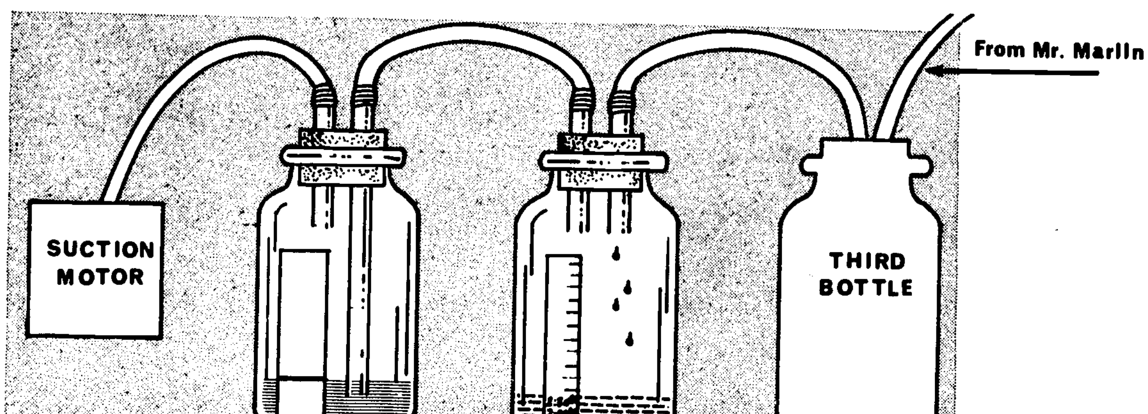
Which of the following represents Mr. Marlin's mechanical suction device?



page 188



page 192



page 198

YOUR ANSWER: The purpose of the third bottle in Mr. Marlin's mechanical suction system is to create negative pressure in the pleural space.

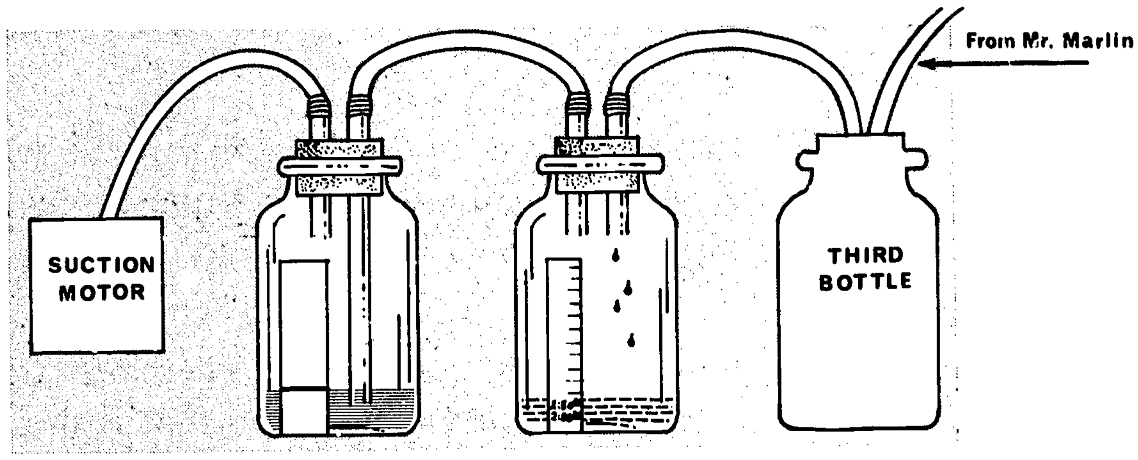
No, the suction motor does that.

Remember that the closed drainage system up to the point of the water-seal is an extension of the pleural space. When negative pressure is present in the closed drainage system, it is also present in the patient's pleural space.

Most suction motors create a degree of negative pressure (suction) which, if applied to the pleural space, would damage the lung tissue. Therefore, this pressure must be modified so that it will be just the right amount. And that is the purpose of the third bottle.

Please RETURN to page 185 and choose the correct answer.

YOUR ANSWER: This diagram represents Mr. Marlin's mechanical suction device:



Wrong.

If the patient's drainage tubing is not connected to the drainage collection bottle, it will be impossible for drainage to collect in that bottle.

Also, we said that the third bottle is connected to the former "air vent" on the water-seal bottle.

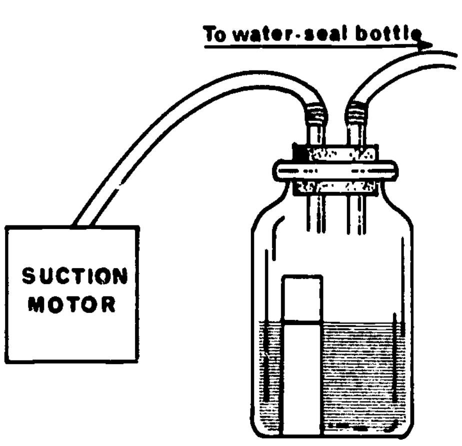
Please RETURN to page 196 and read the information again before selecting the correct diagram.

YOUR ANSWER: The purpose of the third bottle in Mr. Marlin's mechanical suction system is to regulate the amount of pressure in the system.

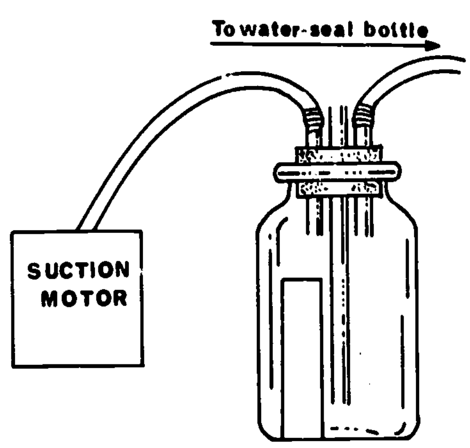
Correct. Since most suction motors create too much suction for this purpose, the third bottle is necessary to regulate the amount of suction in the system (and therefore in the pleural space).

Now, let's describe the appearance of the third bottle. We did say earlier that it is connected to the former air vent on the water-seal bottle and to the suction motor. The tubing which makes these two connections is attached to two short glass or metal tubes which extend about an inch into the third bottle through a rubber stopper. One end of a third, much longer, glass tube extends below water within the bottle; at the other end this tube is open to the atmosphere.

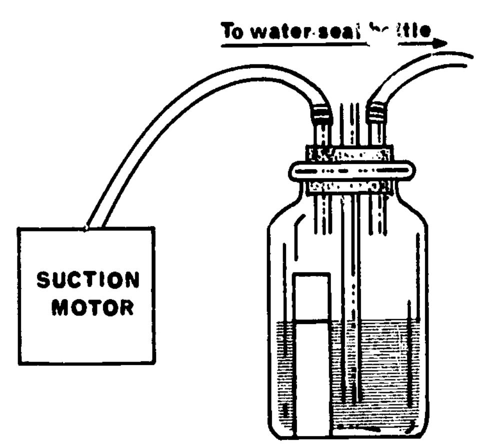
Which of the following represents the third bottle in Mr. Marlin's mechanical suction apparatus?



page 202



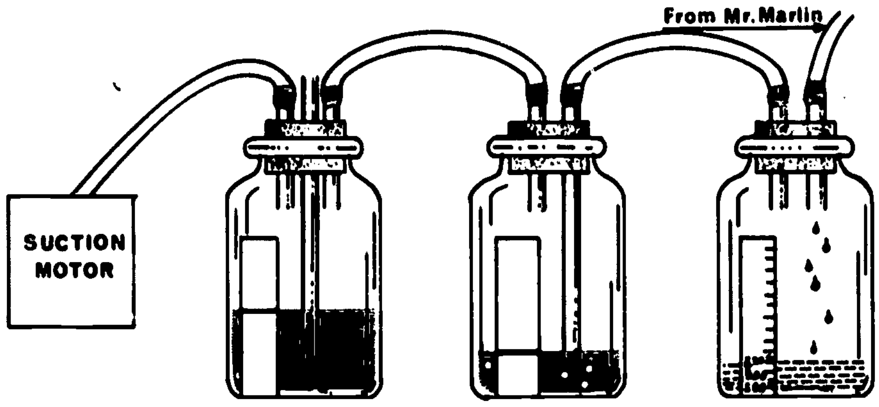
page 205



page 210

(from page 203)

YOUR ANSWER: This diagram shows Mr. Marlin's mechanical suction apparatus working properly:



Wrong.

We said that constant bubbling in the pressure-regulator bottle is an indication of proper functioning of the mechanical suction apparatus. In the diagram you chose, there is no bubbling in the pressure-regulator bottle.

If there is constant bubbling in the water-seal bottle, an air leak may be present. As with the simple water-seal apparatus, the nurse should try to locate and repair such leakage.

Please RETURN to page 203 and select the correct diagram.

YOUR ANSWER: The submerged length of the control tube determines the degree of pressure in the drainage system.

You're right. The physician decides how much of the control tube should be submerged (generally from 4 to 10 cm.). And the nurse should observe the control tube to make certain it is submerged the prescribed distance.

Now let's see what role the control tube plays in regulating pressure. First, we should understand that pressure can be measured in "cm. of water." Let's suppose Dr. Stone wants pressure within the system to be 8 cm. of water. Therefore, he extends the control tube 8 cm. beneath the surface of the water. He turns on the suction motor.

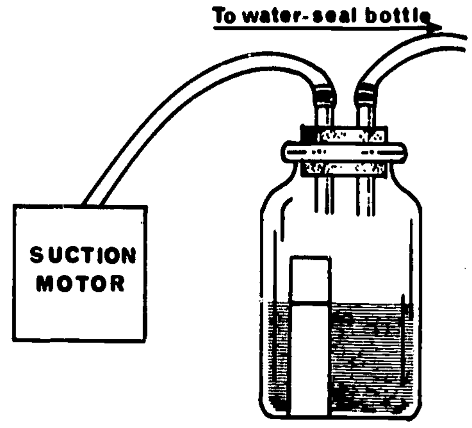
As pressure within the system falls, it pulls (sucks) the 8 cm. column of water in the control tube downward. When pressure in the system falls *below* 8 cm. of water, as much air as is needed to raise the pressure to the desired degree is pulled into the system through the control tube.

What happens to raise pressure within the system when it becomes too low?

Outside air is sucked into the system.	page 203
Water is sucked upward in the control tube.	page 209
Water in the control tube is pulled downward.	page 211

(from page 199)

YOUR ANSWER: This diagram represents the third bottle in Mr. Marlin's mechanical suction apparatus:



Wrong.

You forgot one very important detail—the long tube which extends below water within this bottle. The other end of this long tube is open to the atmosphere.

Please RETURN to page 199 and select the correct diagram.

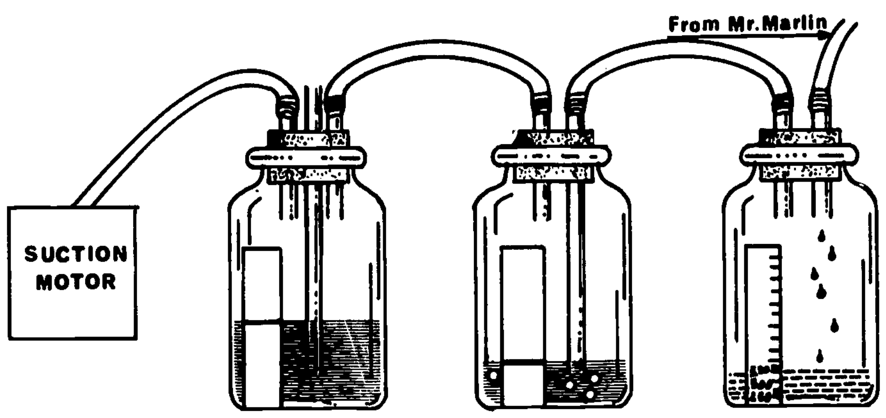
YOUR ANSWER: To raise pressure within the system when it becomes too low, outside air is sucked into the system.

Correct. When pressure falls too much, just enough air to raise it to the desired degree is pulled into the system through the control tube. Therefore, the nurse should make certain the upper end of the control tube is always open to the atmosphere.

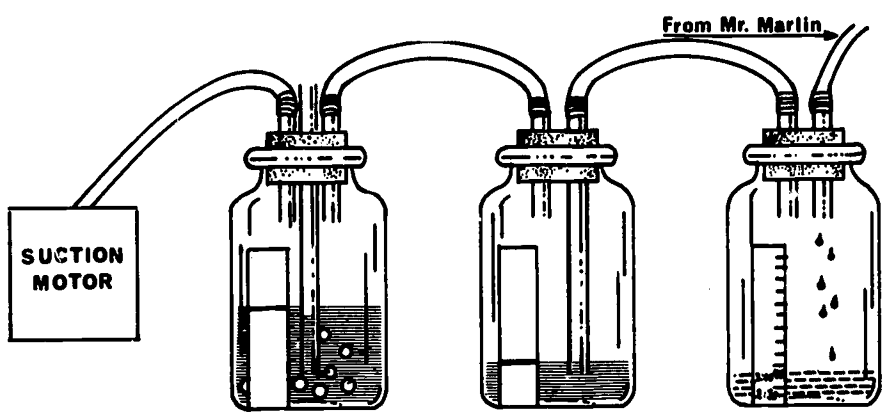
The continuous "sucking-in" of outside air results in constant bubbling in the pressure-regulator bottle. This bubbling, therefore, is an indication of proper function.

You'll recall that up-and-down fluctuation of water indicated proper function in the simple water-seal system. When the water-seal bottle is part of an operating mechanical suction device, however, this water generally remains at a fixed level; it usually does not fluctuate. Constant bubbling in the water-seal bottle still denotes air leakage, which should be corrected as described earlier.

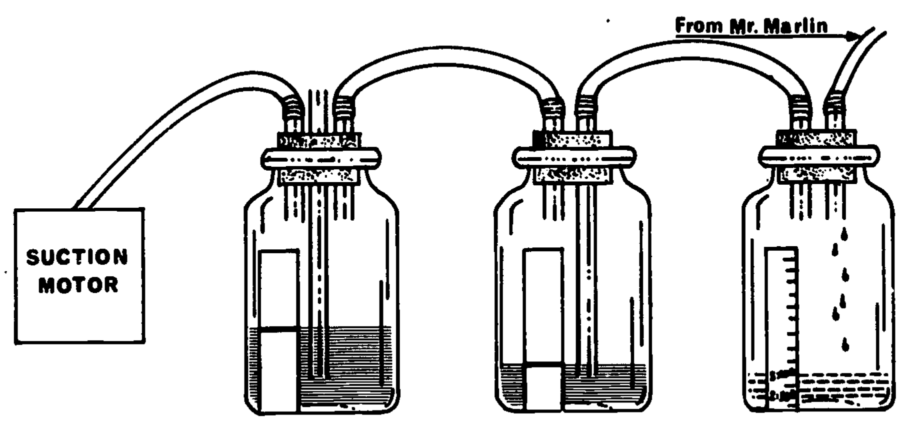
Which diagram shows Mr. Marlin's mechanical suction apparatus working properly?



page 200



page 213



page 221

(from page 210)

YOUR ANSWER: The depth of water in the third bottle determines the degree of pressure in the drainage system.

Wrong.

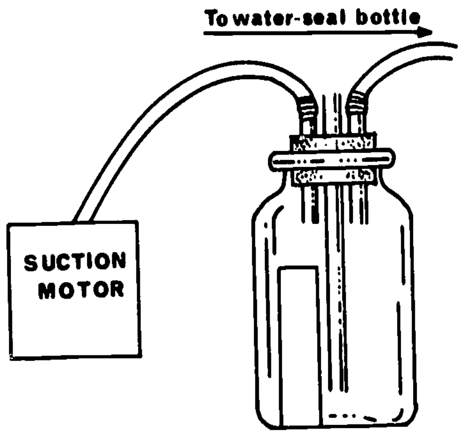
We said that the quantity of water (or depth of water) in the third bottle is *not* the important thing. To be sure, there must be enough water in this bottle so that the control tube can be submerged to the desired distance.

But it is not the depth of water in the bottle which regulates pressure in the system. The distance that the control tube extends into this water is the important factor.

Please RETURN to page 210 and select the correct answer.

(from page 199)

YOUR ANSWER: This diagram represents the third bottle in Mr. Marlin's mechanical suction apparatus:



Almost right.

But don't forget the water within the bottle. Without this water, the regulator bottle could not do its job (we'll talk about this soon).

Please RETURN to page 199 and select the correct diagram.

REVIEW OF SECTION III

On a separate piece of paper, write down the word or words missing from each of the following sentences:

1. Drainage is facilitated when the patient lies on his ——— ———.
2. The drainage apparatus must be kept at a level ——— than the patient's chest.
3. Occlusion of the drainage tubing can lead to compression of the ——— and ———.
4. When the drainage tubing is occluded, re-expansion of the lung can be impossible because of ——— and/or ——— in the pleural space.
5. To facilitate drainage, the drainage tubing should fall in a ——— ——— to the apparatus.
6. The drainage tubing should be "milked" regularly to prevent ———.
7. The drainage tubing should be checked regularly for ———.
8. ——— the connecting points will help assure that the apparatus is airtight.
9. The drainage tubing must be airtight in order to restore ——— intrapleural pressure.
10. Rapid shallow breathing and cyanosis can be indications of ——— ———.
11. If the drainage apparatus is elevated above the level of the chest, there may be ——— of ——— into the chest.
12. In the water-seal bottle, the purpose of submerging the open tip of the long tube in water is to ——— ——— from entering the pleural space.

To continue, please go on to page 207.

13. A rapidly fatal complication associated with closed chest drainage is ———— ————.

14. The leaking in and trapping of air in the pleural space can result in ———— ————.

15. The short glass tube in the water-seal bottle is left open to the atmosphere so that ———— can ———— from the bottle.

16. To guard against the danger of disrupting negative intrapleural pressure, the patient should be accompanied by ———— at all times.

17. In the water-seal system, ——— of the water indicates proper functioning of the apparatus.

18. Intrapleural pressure can become excessive when the concentration of molecules within the pleural space ————.

19. On tape placed on the drainage collection bottle, the nurse should record the ———— and ———— of drainage.

20. The mechanical suction apparatus ———— fluid and air from the pleural space.

21. When tension pneumothorax (and/or mediastinal shift) is suspected, the first thing to do is ———— a ————.

22. Before disconnecting the apparatus from the drainage tubing (e.g., for replacement), the patient's chest catheters must be ————.

23. The purpose of the third bottle in the mechanical suction apparatus is to ———— pressure in the system.

24. When replacing a drainage apparatus, measures must be taken to keep the pleural space ———— to the atmosphere.

To continue, please go on to page 208.

(from page 207)

25. Leakage of air into the drainage system (whether water-seal or mechanical suction) is indicated by ——— ——— in the water-seal bottle.

26. Collection of drainage in a separate bottle in the water-seal system facilitates measurement of the drainage fluid and ——— of intrapleural air.

27. If it appears that air is leaking into the drainage system, the nurse should try to ——— and ——— the leak.

28. If the patient shows signs of tension pneumothorax while his chest catheters are clamped, the nurse may have to ——— the clamps.

29. An indication that all intrapleural fluid and air have been evacuated is ——— of fluctuation of water in the water-seal bottle.

30. Whenever the suction motor is off, a vent for intrapleural air must be provided by ——— the ——— from the motor.

31. The degree of pressure in the mechanical suction system is determined by the ——— length of the control tube.

32. Proper functioning of the mechanical suction apparatus is indicated by ——— ——— in the "regulator" bottle.

33. When pressure within the mechanical suction system becomes too low, it is raised by sucking ——— ——— into the system.

34. An air leak into the system can be located by clamping the tubing at a point ——— the leak.

35. In the mechanical suction system, the suction motor is turned off occasionally to determine whether evacuation of fluid and air is ———.

To check your answers, please turn to page 214.

YOUR ANSWER: To raise pressure within the system when it becomes too low, water is sucked upward in the control tube.

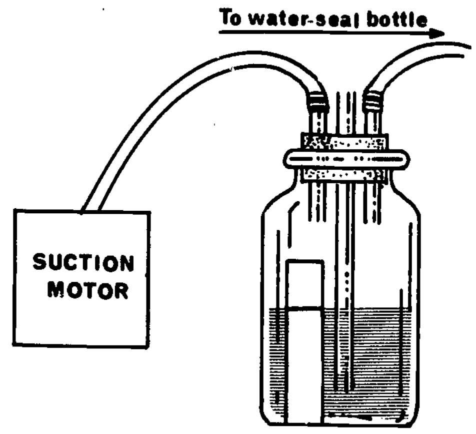
Wrong.

When pressure falls below the desired degree (as determined by the submerged length of the control tube), water is sucked downward in the control tube.

The important idea involves the fact that this control tube is open to the atmosphere at the other end. And when pressure falls below the desired degree, air is pulled into the tube. This air, having a higher degree of pressure than that in the drainage system, raises the pressure within the system to the desired degree. Only as much air as is needed is pulled into the tube.

Please RETURN to page 201 and select the best answer.

YOUR ANSWER: This diagram represents the third bottle in Mr. Marlin's mechanical suction apparatus:



You are right. One end of the long glass tube extends below the water within the bottle, and the other end of the tube is open to the atmosphere. We're going to call this tube the "control tube."

The control tube is important because it is the depth of submersion of the control tube in water which controls the pressure within the drainage system.

In other words, the quantity of water in the third bottle is not the important thing (of course there must be enough so that the tube can be submerged the desired distance). But it is the distance that the control tube extends into the water that regulates pressure in the drainage system.

The physician decides how much of the tube should be submerged, and this may vary from case to case. Generally, however, it will be from 4 to 10 cm.

What determines the degree of pressure in the drainage system?

The submerged length of the control tube.	page 201
The depth of water in the third bottle.	page 204
The length of the control tube.	page 212

YOUR ANSWER: To raise pressure within the system when it becomes too low, water in the control tube is pulled downward.

Not exactly.

It's true that the column of water within the control tube is pulled downward when the suction motor is on. The important idea, however, involves the fact that the control tube is open to the atmosphere.

When pressure falls below the desired degree, outside air is pulled into the system through the control tube. This air, having a higher degree of pressure than that in the drainage system, raises pressure within the system to the desired degree.

Please RETURN to page 201 and select the best answer.

YOUR ANSWER: The length of the control tube determines the degree of pressure in the drainage system.

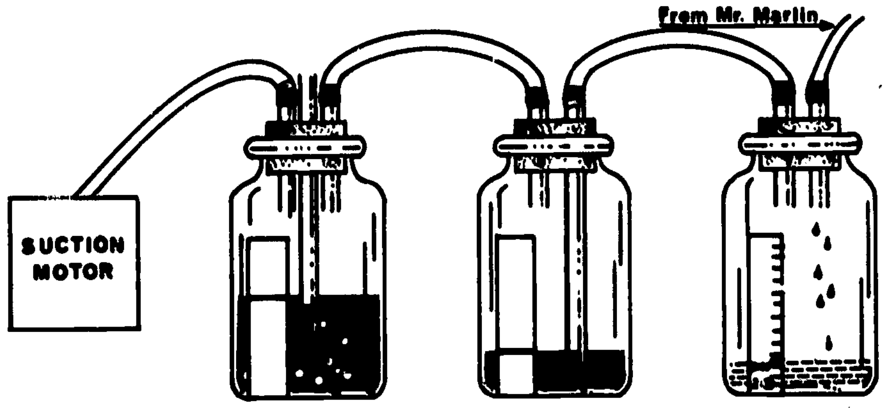
No.

The length of the control tube which is under water is the factor which regulates pressure in the system.

There must be enough water in the bottle so that the control tube can be submerged the desired amount. The physician decides how much of the tube should be submerged; generally it will be from 4 to 10 cm.

Please RETURN to page 210 and select the correct answer.

YOUR ANSWER: This diagram shows Mr. Marlin's mechanical suction apparatus working properly:



Correct. There is constant bubbling in the pressure-regulator bottle, and this indicates proper function. Miss Wilson should observe the pressure-regulator bottle to make certain that the water in it bubbles continuously. (Note that the water level on both the pressure-regulator and the water-seal bottle is recorded on marking tape.)

You'll recall that the main indication of proper functioning of the simple water-seal system is fluctuation in the water-seal bottle. And we said that absence of fluctuation is a clue to the complete evacuation of intrapleural fluid and air.

Now — since this water generally doesn't fluctuate when it is part of the mechanical suction apparatus, what will alert Dr. Stone and Miss Wilson to the possibility that all fluid and air have been evacuated? Or that evacuation has ceased because of clogged tubing? To check on these possibilities, the apparatus must be modified so that it can be observed as a water-seal system.

Why might Dr. Stone turn off Mr. Marlin's suction motor? To determine whether the:

Drainage tubing is airtight. page 218
Control tube is working properly. page 220
Drainage system is no longer needed. page 222

(from page 208)

Here are the correct answers to the first part of our review of Section III. Check your answers against these.

1. Drainage is facilitated when the patient lies on his *affected side*.

2. The drainage apparatus must be kept at a level *lower* than the patient's chest.

3. Occlusion of the drainage tubing can lead to compression of the *lungs* and *mediastinum*.

4. When the drainage tubing is occluded, re-expansion of the lung can be impossible because of *fluid* and/or *air* in the pleural space.

5. To facilitate drainage, the drainage tubing should fall in a *direct* (straight) *line* to the apparatus.

6. The drainage tubing should be "milked" regularly to prevent *clogging*.

7. The drainage tubing should be checked regularly for *patency*.

8. *Taping* the connecting points will help assure that the apparatus is airtight.

9. The drainage tubing must be airtight in order to restore *negative* intrapleural pressure.

10. Rapid shallow breathing and cyanosis can be indications of *tension pneumothorax* (mediastinal shift).

11. If the drainage apparatus is elevated above the level of the chest, there may be a *backflow* (siphoning) of *fluid* into the chest.

12. In the water-seal bottle, the purpose of submerging the open tip of the long tube in water is to *prevent air* from entering the pleural space.

13. A rapidly fatal complication associated with closed chest drainage is *tension pneumothorax* (mediastinal shift).

Please go on to page 215.

14. The leaking in and trapping of air in the pleural space can result in *tension pneumothorax* (mediastinal shift).

15. The short glass tube in the water-seal bottle is left open to the atmosphere so that *air* can *escape* from the bottle.

16. To guard against the danger of disrupting negative intrapleural pressure, the patient should be accompanied by *hemostats* at all times.

17. In the water-seal system, *fluctuation* of the water indicates proper functioning of the apparatus.

18. Intrapleural pressure can become excessive when the concentration of molecules within the pleural space *increases*.

19. On tape placed on the drainage collection bottle, the nurse should record the *quantity* and *rate* of drainage.

20. The mechanical suction apparatus *pulls* (sucks) fluid and air from the pleural space.

21. When tension pneumothorax (and/or mediastinal shift) is suspected, the first thing to do is *notify* (call) a *physician*.

22. Before disconnecting the apparatus from the drainage tubing (e.g., for replacement), the patient's chest catheters must be *clamped*.

23. The purpose of the third bottle in the mechanical suction apparatus is to *regulate* pressure in the system.

24. When replacing a drainage apparatus, measures must be taken to keep the pleural space *closed* to the atmosphere.

Please go on to page 216.

(from page 215)

25. Leakage of air into the drainage system (whether water-seal or mechanical suction) is indicated by *constant bubbling* in the water-seal bottle.

26. Collection of drainage in a separate bottle in the water-seal system facilitates measurement of the drainage fluid and *evacuation* of intrapleural air.

27. If it appears that air is leaking into the drainage system, the nurse should try to *locate* and *repair* the leak.

28. If the patient shows signs of tension pneumothorax while his chest catheters are clamped, the nurse may have to *release* the clamps.

29. An indication that all intrapleural fluid and air have been evacuated is *lack* (absence) of fluctuation of water in the water-seal bottle.

30. Whenever the suction motor is off, a vent for intrapleural air must be provided by *disconnecting* the *tubing* from the motor.

31. The degree of pressure in the mechanical suction system is determined by the *submerged* length of the control tube.

32. Proper functioning of the mechanical suction apparatus is indicated by *constant bubbling* in the "regulator" bottle.

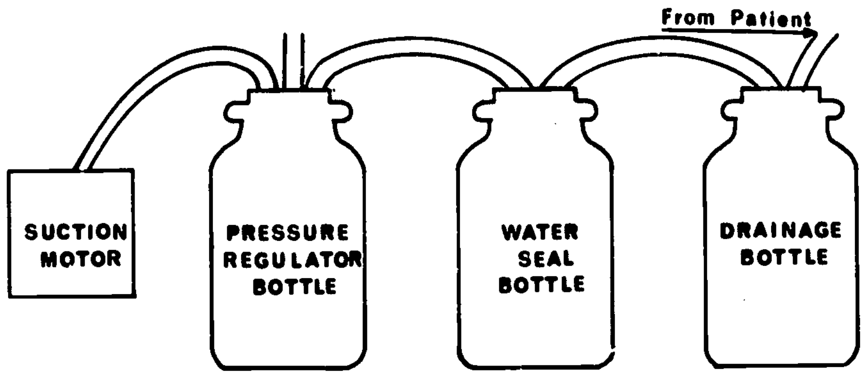
33. When pressure within the mechanical suction system becomes too low, it is raised by sucking *outside air* (the atmosphere) into the system.

34. An air leak into the system can be located by clamping the tubing at a point *below* the leak.

35. In the mechanical suction system, the suction motor is turned off occasionally to determine whether evacuation of fluid and air is *complete*.

Please turn to page 223.

YOUR ANSWER: This diagram illustrates what should be done when Mr. Marlin's suction motor is turned off:



Wrong.

The diagram you chose shows the closed drainage system with all of the tubing still in place for operation as a mechanical suction apparatus.

Remember this: Whenever the motor is off, the drainage system *must* be opened to the atmosphere. There must be a vent through which intrapleural air can leave the system. To provide this vent when the motor is turned off, the tubing should be detached from the motor and left open at this point.

Please RETURN to page 222 and select the correct diagram.

(from page 213)

YOUR ANSWER: Dr. Stone might turn off Mr. Marlin's suction motor to determine whether the drainage tubing is airtight.

No.

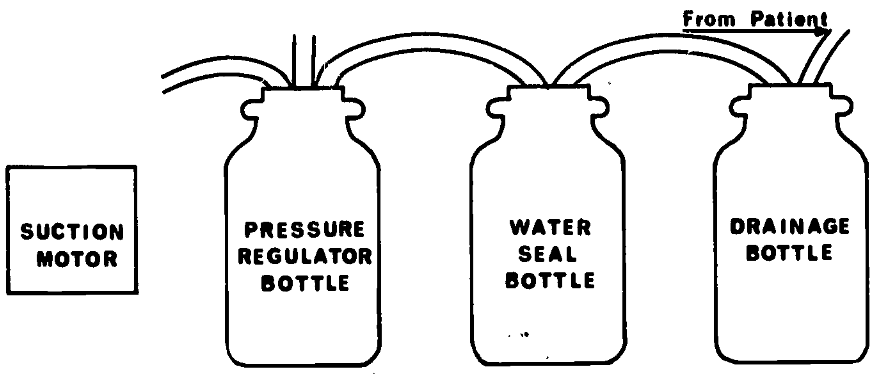
This would, however, be a way to determine whether the drainage tubing is patent. And Dr. Stone might wish to turn off the motor from time to time in order to check on the patency of the tubing (proper functioning of the water-seal system).

Another reason he will want to observe the apparatus as a simple water-seal system is to check on whether evacuation of intrapleural fluid and air is complete.

Remember that air leakage generally will result in bubbling in the water-seal bottle whether or not the suction motor is on.

Please RETURN to page 213 and select the correct answer.

YOUR ANSWER: This diagram illustrates what should be done when Mr. Marlin's suction motor is turned off:



Correct.

Whenever the motor is off, tubing should be detached from the motor and left open to the atmosphere, thus providing a vent through which intrapleural air can escape from the system.

In essence, turning off the motor and disconnecting the tubing in this manner modifies the apparatus so that it becomes a simple water-seal system.

To help you remember them, here again are the few important "guides" which pertain *only* to the mechanical suction apparatus:

1. *Mechanical suction apparatus: observe the control tube to make certain it is submerged the prescribed distance.*
2. *Mechanical suction apparatus: make certain the upper end of the control tube is open to the atmosphere.*
3. *Mechanical suction apparatus: observe pressure-regulator bottle for constant bubbling which indicates proper functioning.*
4. *Mechanical suction apparatus: whenever the motor is off, disconnect tubing from motor to provide a vent for intrapleural air.*

* * *

We have come to the end of our discussion. Now to conclude the course, let's review the important ideas we've presented to you in this section concerning the apparatus.

Please turn to page 206.

YOUR ANSWER: Dr. Stone might turn off Mr. Marlin's suction motor to determine whether the control tube is working properly.

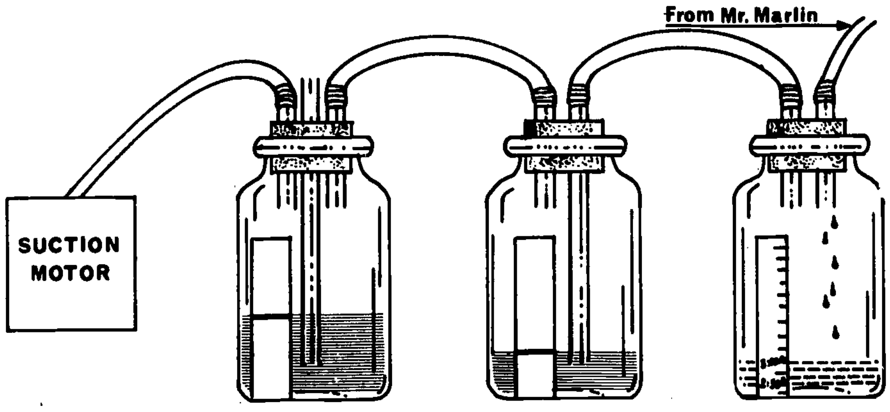
Wrong.

The main indication that the control tube is functioning as it should be is the continuous bubbling in the pressure-regulator bottle. We've just discussed the fact that when the mechanical suction apparatus is working properly, air is constantly sucked into the system through the control tube. (This results in constant bubbling in that bottle — remember?)

The point here is that it is necessary to observe the apparatus as a simple water-seal system from time to time because absence of the characteristic fluctuation indicates either obstructed tubing or complete evacuation of intrapleural fluid and air.

Please RETURN to page 213 and select the correct answer.

YOUR ANSWER: This diagram shows Mr. Marlin's mechanical suction apparatus working properly:



Wrong.

We said that constant bubbling in the pressure-regulator bottle is an indication of proper functioning of the mechanical suction apparatus. In the diagram you chose, there is no bubbling in the pressure-regulator bottle.

As with the simple water-seal apparatus, constant bubbling in the water-seal bottle indicates the presence of an air leak. The nurse should try to locate and repair such leakage.

Please RETURN to page 203 and select the correct diagram.

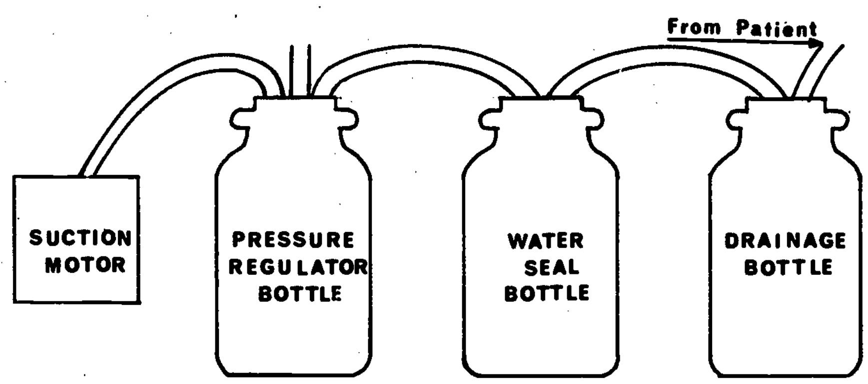
YOUR ANSWER: Dr. Stone might turn off Mr. Marlin's suction motor to determine whether the drainage system is no longer needed.

That's right. Dr. Stone probably will want to observe the apparatus as a simple water-seal system occasionally because absence of the characteristic fluctuation indicates complete evacuation of fluid and air. (It also indicates malfunction due to obstructed tubing.)

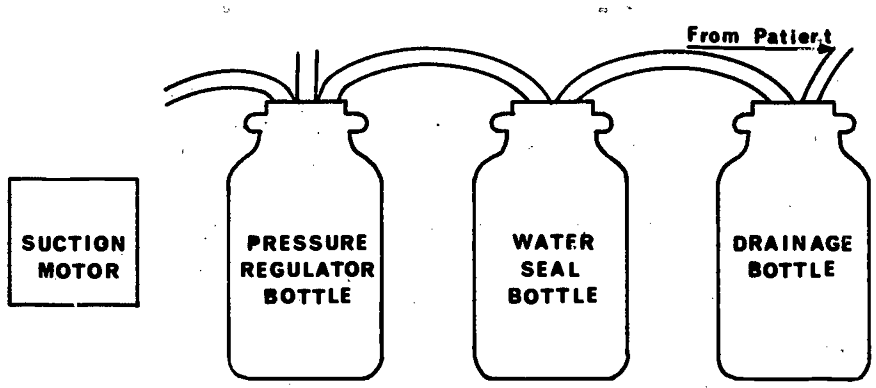
Whenever the motor is off, the drainage system must be opened to the atmosphere so that intrapleural air can escape from the system.

When the motor is on, intrapleural air leaves the closed system via the exhaust on the motor. But when the motor is off, a vent for this air must be provided by detaching the tubing from the motor, thus leaving the system open to the atmosphere at this point. If there is no way for intrapleural air to escape, pressure within the system can increase to the point that it causes tension pneumothorax.

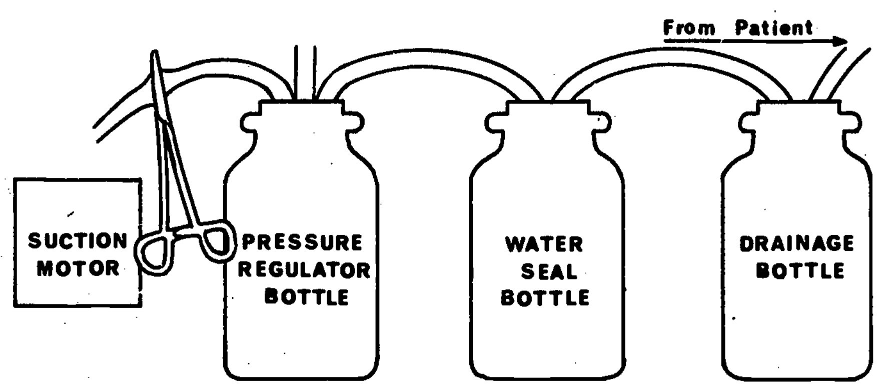
Which diagram shows what should be done when the suction motor is turned off?



page 217



page 219

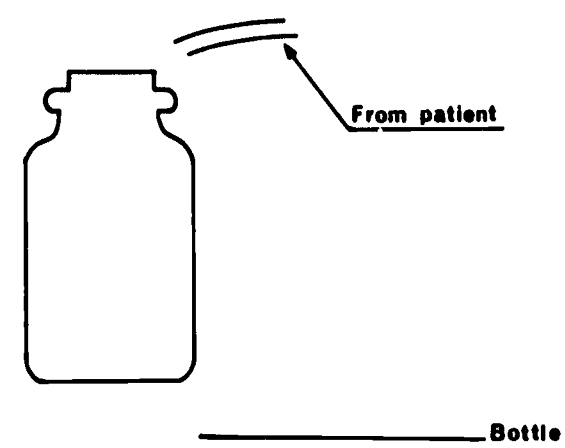


page 224

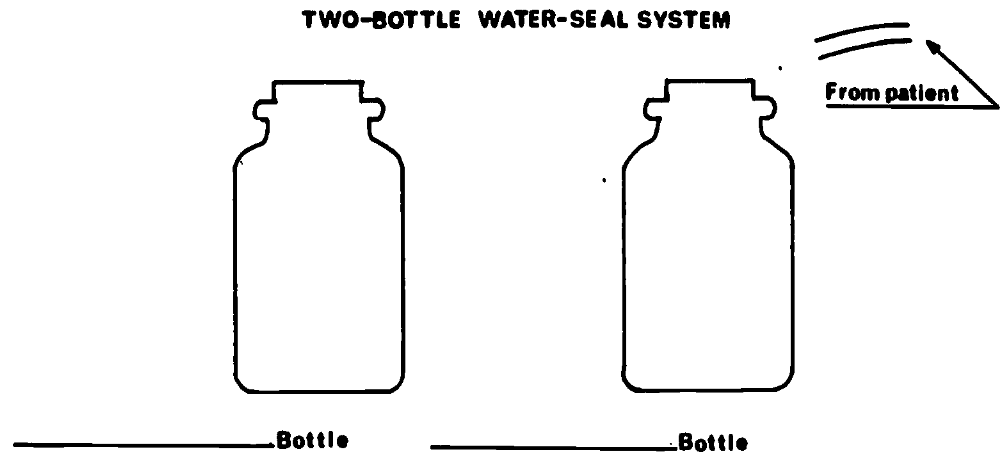
The following are outlines of both water-seal and mechanical suction systems. You may wish to see if you can draw these outlines with all of the appropriate details—including tubes, tubing, water, tape, and signs of proper functioning.

(Use a separate piece of paper for your drawings.)

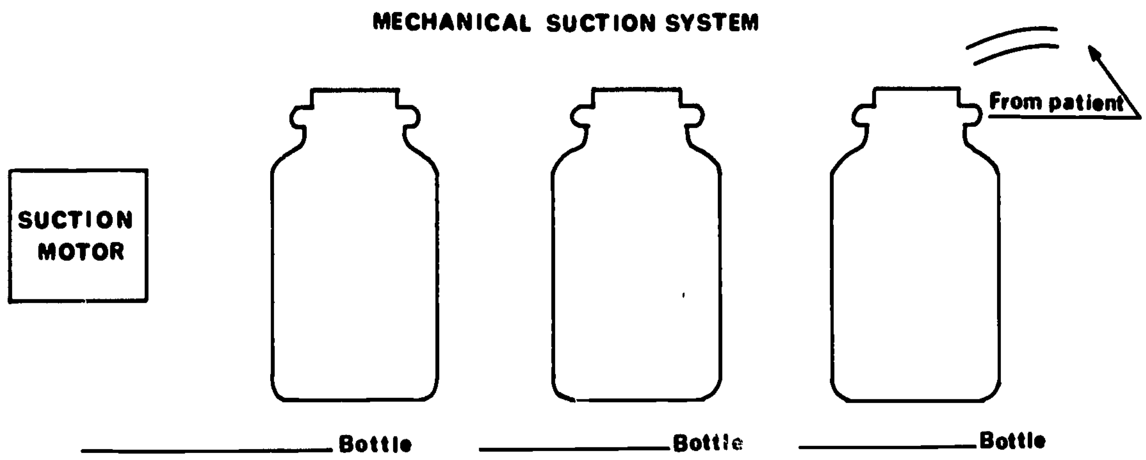
ONE-BOTTLE WATER-SEAL SYSTEM



TWO-BOTTLE WATER-SEAL SYSTEM



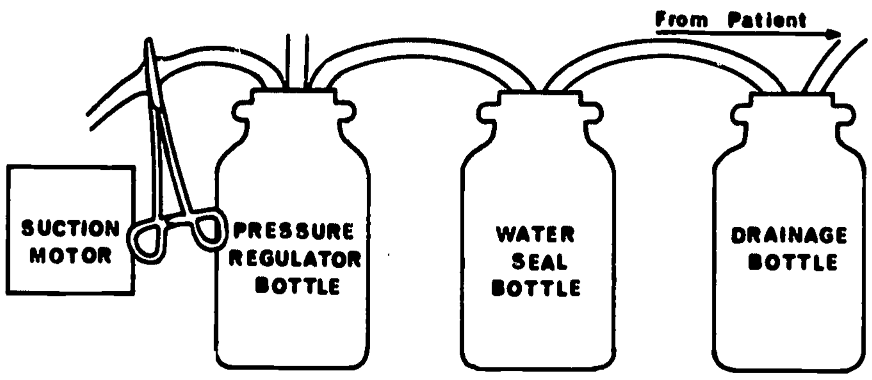
MECHANICAL SUCTION SYSTEM



To check your drawings, please turn to page 225.

(from page 222)

YOUR ANSWER: This diagram illustrates what should be done when Mr. Marlin's suction motor is turned off:



Wrong.

You're right that the tubing should be detached from the suction motor as shown in the diagram you chose. However, this tubing *must* be left open to the atmosphere when the motor is off; it should *not* be clamped.

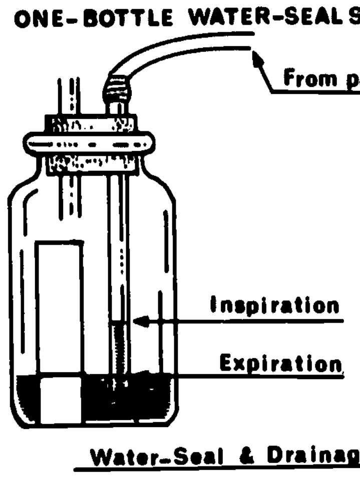
Leaving the tubing open at this point in the apparatus provides a vent through which intrapleural air can leave the system. Without this vent, pressure within the system can rise until it causes tension pneumothorax. This is true only when the motor is off. With the suction motor on, intrapleural air leaves the system via the exhaust on the motor.

Please RETURN to page 222 and select the correct diagram.

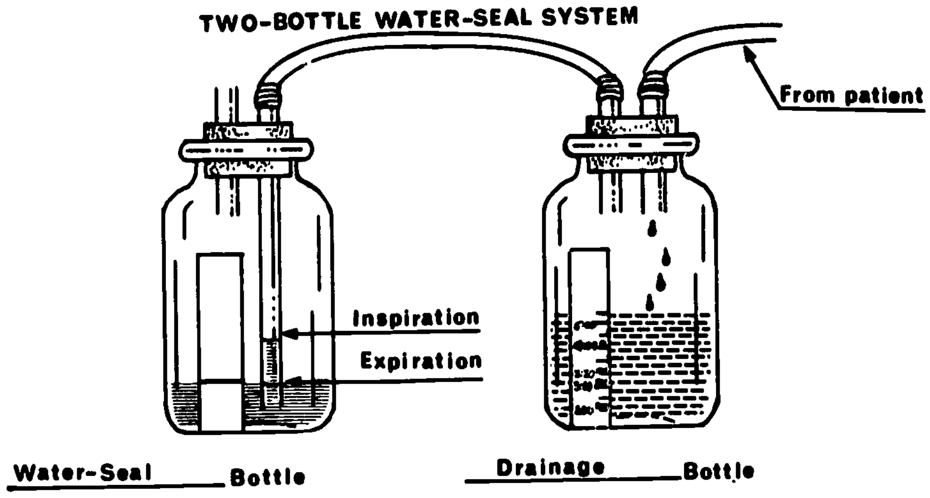
(from page 223)

Here are the outlines again, this time including all of the details: (Check your drawings against these.)

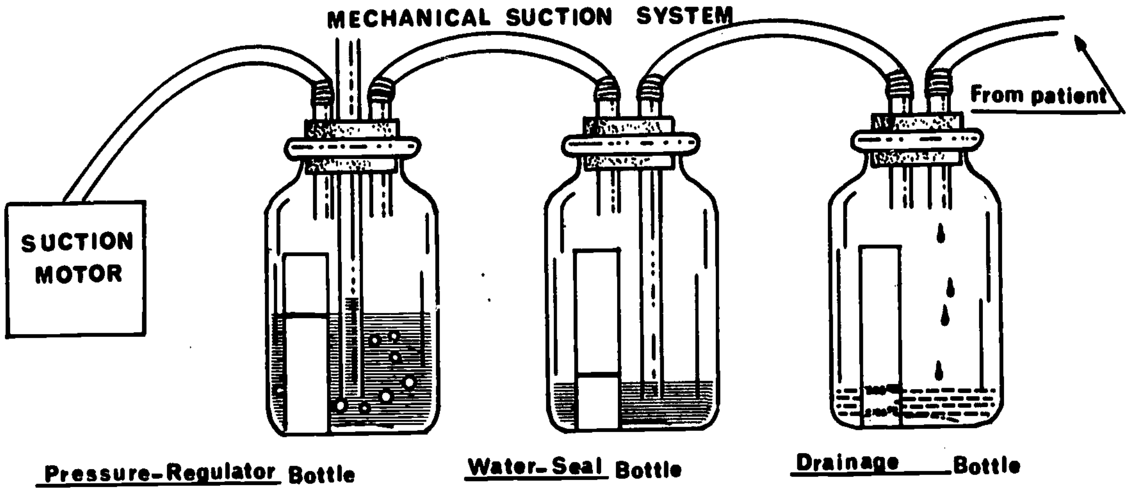
ONE-BOTTLE WATER-SEAL SYSTEM



TWO-BOTTLE WATER-SEAL SYSTEM



MECHANICAL SUCTION SYSTEM



This concludes our course on closed drainage of the chest.

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